THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 14 APRIL, 1950 NUMBER 2

PROBLEMS AND NEEDS IN PHEASANT RESEARCH*

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A mid-century appraisal of our professional competence to deal with small-game management problems would indicate important regional progress for several species. We probably know at least a few things that can be done in some areas to have more quail, more rabbits, and more squirrels.

Applying this same test to the introduced pheasant, however, gives little cause for satisfaction. Our knowledge and skills are inadequate to the job we are called upon to do. The measures commonly relied upon for this species might be called "desperation management" and, whether deliberately or not, they are in use for want of something better.

It is true we know how to produce more food for a local flock of wintering birds. We can keep a few cocks safe from the hunter with posted refuges. Additional cover will help to foil both hunter and fox, and predator control by direct attrition may preserve some birds at least seasonally. But the country's best pheasant range is producing without such expedients and their use in marginal range has yielded little if anything in year-to-year increases. Evidently we are not getting down to real "limiting factors."

Of course, we can side-step the management problem completely on a small scale by rearing birds on game farms and turning them out immediately before the season on small intensively hunted areas. Under these conditions we may bring 50 to 80 per cent of the cocks to bag. For one day this may satisfy the individual gunner, although by ordinary standards such sport rates rather low as outdoor recreation. Actually, there is nothing wrong even with a shooting gallery, as long as the individual participants pay the full bill for what they get. We can question whether it is sound to use the license fees of several hunters to give temporary satisfaction (as contrasted with really good hunting) to one individual when all might be benefited by spending the money in another way.

Here the research man should step in and tell us how the money should be spent. He probably can do a fairly good job if the entire wildlife program is considered. But in most areas, getting pheasants for those funds is beyond us at present. Considering the needs of "action" programs, it is difficult to find anything anywhere to cite as a

* Presented at the Northeast Wildlife Conference, Syracuse, N. Y., Feb. 3, 1950.

reliable and proved technique which will produce more birds at a fair price. This in spite of the fact that at least 25 states now have research projects on the pheasant (Wandell 1949). It is appropriate to ask: "What are we learning?"

In studying this bird, the biologist has the frequent and disquieting experience of having to admit that some of the most significant things he "knows" about it—are not completely true.

This species, we say, is a bird of the north—yet it recently has become established on irrigated lands in New Mexico at a latitude near that of Savannah, Georgia. But even this is not the southern limit. There are ringnecks south of the Rio Grande and in Baja California. The Schwartzes (1949) describe a wide variety of conditions occupied by pheasants in the islands of Hawaii, from sea level to 10,000 feet and from tropical areas to regions of freezing temperatures.

Pheasants thrive best on glaciated soils —or do they? Some of the largest per-acre yields of this bird now are being taken on the unglaciated ricefields of California's Sacramento Valley (Ferrel, Harper, and Hiehle 1949).

The Chinese ringneck is associated with agricultural lands, and particularly grain-farming areas. It is a bird of fertile soils. And although these things are characteristic, again there are exceptions: Fairly respectable populations are found in relatively infertile and uncultivated parts of the Nebraska Sandhills (Sharp and McClure 1945), and there are birds in the forest and range lands of Hawaii.

We need a broad view of the pheasant. Studies that do not see beyond the borders of a state can easily go wrong. On the other hand, there are important differences between regions. Fifteen years ago a widespread impression existed that winter survival was a big problem in eastern pheasant management. Food patches, winter feeding, and cover plantings were prescribed as the key to better hunting. Today, in the region between Chicago and Boston, you will hear little talk about such methods, and little indeed about starvation or winter-killed pheasants. These resourceful birds have been watched through too many winters by too many critical observers.

But proceed west from Lake Michigan into that land of rich unleached soils where the buffalo roamed and where Dakota grainfields now form the nation's best *extensive* pheasant range. Here prairie blizzards point up the reduction of cover to its irreducible minimum and starvation losses become a convincing reality.

It seems that practically all our generalizations fail to describe the pheasant accurately because the species itself is generalized. The Chinese ringneck is widely successful because it is a natural cosmopolite and we are not likely to appreciate its full possibilities until someone has gathered notes and eggs across Asia on the trail of Marco Polo from the Caucasus to Formosa.

What happened to pheasant populations during the forties, on almost a national scale, certainly highlights our ignorance of this bird in particular and some wildlife fundamentals in general.

On a basis of past experience, it was reasonably predictable that the early forties would bring another periodic reduction in certain native birds and mammals. It came in a degree that was unmistakable, and for most areas 1942

and 1943 were the most eventful years. By 1944 it was evident that widespread declines had occurred in hares and rabbits and native grouse. It is significant to note that, beginning perhaps a year or two earlier, there were extensive reductions in the numbers of common birds and mammals in northwestern Europe, including such species as black game, capercaille, willow grouse, hazel grouse, (Hungarian) partridge, pheasant, and varying hare (Siivonen 1948).

In this country the Hungarian partridge had previously shown a tendency to participate in the population rhythms of native species. That the pheasant would get into the "swing of things" in the forties was not, to my knowledge, specifically anticipated by anyone.

In the Midwest, at least, it did just that. On areas under my own observation in Michigan, 1941 was an exceptionally favorable year for both pheasants and rabbits. Both were plentiful in 1942, although pheasants were reduced from the peak of the year before. It is interesting and perhaps significant that Grange (1949, p. 122) observed the same trend in Wisconsin ruffed grouse. In 1943 conditions appear to have degenerated for both pheasant and grouse over a wide area.

This important phenomenon occurred in the midst of the war at a time when research projects were being radically curtailed. Nevertheless, enough investigators were on the job so that, if truly *effective* observational and sampling techniques had been in use, it should have been possible to establish beyond question exactly what happened to the pheasant.

Although there is no precise proof on this point, there does seem to be a fairly general agreement that a persistent unfavorable trend in spring weather occurred for several years in widely scattered areas and that this is the one *observed* factor which might have caused such a widespread reduction. As would be expected, observations in some localities implicated weather more clearly than in others (Allen 1946, 1947; Carlson 1946; Einarsen 1946; Ginn 1948; Perry 1946), although poor nesting success and unfavorable age ratios were reported from nearly every region where pheasants were being studied (Bach 1946; Faber 1946; Hendrickson 1944; Kimball 1948; Leedy and Dustman 1948; Lundy 1946; Mohler 1948; Nelson 1948). Published observations are borne out by the results of Wandell's (1949) questionnaire and the records gathered by Kimball (1948) through correspondence. Impaired reproduction is agreed upon and suggestive weather trends are prominently mentioned.

Suggestive also is the fact that during the years of the decline, when spring weather tended to be wet, or wet and cold, in many localities, the center of distribution for South Dakota pheasants shifted westward toward the dryer part of the state (Kimball 1948). On a trip to Colorado in 1948 I tried by personal inquiry to determine whether there had been any decline of pheasants in the irrigated area of northeastern Colorado where wet spring weather would not be a factor. I could find no one who had heard of a decline in that area, and Wandell (1949) evidently got a similar reply from the state. He brings out the fact that recovery from the slump has been most rapid on the west coast, and we might add that a similar resilience has been evident in

the birds on Pelee Island in Lake Erie where a complete return to abundance was attained in 1948 and 1949.

In discussing weather, it should be mentioned that Cartwright (1944) definitely ascribed the drastic reduction in 1942–43 of sharptailed grouse and Hungarian partridges in the prairie provinces of Canada to below-normal temperatures and above-normal precipitation during the hatching period, which suggests that the synchronism among farmland pheasants, plains inhabiting sharptails and Hungarians, and forest dwelling ruffed grouse is not a matter of chance. Waiting to be included also, of course, are the mammals. Grinnell's (1939) observation of a wet-year reduction in California small mammals indicates that this is a reasonable possibility.

It is logical to suspect that these large-scale decreases are related, and if they are, then the total phenomenon is not covered adequately by Grange's (1949) penetrating but necessarily incomplete explanation of cyclic mechanisms. Pelee Island pheasants, for instance, were not affected by a sudden radical change in plant successions, agricultural operations, or in predation pressure. Yet they declined at the same time as bird populations far removed (Clarke 1947; Stokes 1948). It can hardly be doubted that the fundamentals discussed by Grange, including the cyclic nature of weather trends, certainly must be involved in the population rhythms of living things, and his book is an important step toward understanding these primal behaviorisms.

If the decline of game birds and/or mammals was a direct effect of adverse spring weather, it does not appear to be unique, as wildlife literature contains numerous references to such occurrences. In American Game for 1926 the following note appears:

"Thirty years ago, partridges [Hungarians] in England were not doing well. Owing to a succession of seasons in which the Spring of the year was attended by rough, boisterous weather preventing the successful rearing of the young birds, the coveys in most parts of the country had become few and small" (Hunting 1926).

These records which appear to involve weather in the recent pheasant decline have not been cited in an attempt to prove anything. Rather the entire discussion leads to the inescapable conclusion that from coast to coast something big and fundamental happened in the forties not only to the pheasant but to many species of birds and mammals of economic importance. Yet, since the termination of the New York grouse studies in 1942, not a single adequate *research team* has been organized to follow the fate of a species known to be cyclic. It is obvious, of course, that there was no pheasant study intensive enough to identify the specific factors involved in the series of spectacular crop failures. Our impressions of weather probably are significant, but they fall far short of scientific exactitude. There were years and areas where pheasants reproduced satisfactorily in spite of what appeared to be adverse weather. It is evident that we lack a factual concept of the limits within which combinations of climatic variables are important to pheasant reproduction.

We are in the hypothesis stage of development in learning about weather and pheasants. In 1940 Bennitt and

Terrill advanced a suggestion that the southern limit of pheasant distribution in the Midwest might be determined by ground temperatures which could not be tolerated by eggs exposed to the sun. Eight years later, with the same idea in mind, Graham and Hesterberg (1948) drew climatographs (temperature plotted against precipitation) of areas where the species had succeeded. They found that "one segment of all the graphs of localities where the birds have been successful fall in the same area. Between the first of April and the first of June . . . birds experienced similar conditions in all successful localities studied."

Is this significant? And does it relate significantly to effects of weather periodicities during the April-June nesting season in areas where pheasants ordinarily thrive? Thoughtful hypotheses like those cited should be the forerunners of intensive research projects—but are they? How much money is being spent in getting at the elemental facts of our pheasant-climate enigma?

That money is being spent on this species there can be no doubt. In 1930 a summary of stocking activities for the nation indicated that 31 states liberated some 174,000 pheasants (Anon 1930). Eighteen years later, another survey showed that 32 states had stocked roughly 1¼ million birds (Pushee 1948). It is likely that in two or three individual states the yearly expenditure for pheasant management (sic) now approaches or exceeds half a million dollars, and for the entire country artificially stocked birds probably represent a total application of land, labor, and capital exceeding 2½ million dollars. The annual crop of ringnecks is getting attention, and it is a big operation as wildlife operations go. It has a significant relationship to research accomplishments or the dearth thereof.

Ordinarily we conceive of research as being that small-scale trial and error which tests and proves production methods before they are applied in big expensive programs. However, this is a purely theoretical concept as applied to pheasant activities. The research man has consistently found himself tossing like a chip in the backwash of big stocking programs grabbing at a fact here and an indication there in an attempt to find out what was being accomplished. When he had found out, or thought he had, there was no one to listen, for likely enough the administrator who hired him was so busy bringing fulfillment to the action-in-our-time philosophy of a demanding public that the question of *whether* to stock never reared its ugly head.

For anyone with the inspiration to search it out, there is a fairly adequate literature on artificial stocking, although most of the research has been extensive rather than intensive. To a biologist the evidence is convincing that such one-by-one methods are costly and inefficient and that they offer little possibility of achieving real satisfaction for any appreciable segment of the hunting public. Further, it appears that the regular dissipation of funds in this manner delays indefinitely the land management job by means of which the tremendous natural productive capacity of wild populations can be employed to get results on a scale that will really count.

To the biologist all this seems evident, but it is not evident to a public

conditioned to the assumption that all blessings flow from assembly lines and that enough pressure will accomplish anything. Whether or not they live in what can reasonably be considered pheasant country, there is a tendency for some groups to confront their state administration with the alternative of ringnecks or wrung necks, in which situation it is obvious that the most comforting thing a research man could do would be to find out why what the public wants is right. Sadly for the administrator, he seldom gets this comfort. Such a situation is unfortunate, for neither creative art nor creative science can flourish in an or-else atmosphere.

The further research called for by the artificial stocking issue probably is mass tests similar in scope and execution to the project carried out for three years on the Sartain and McManus ranches in California (Ferrel, Harper, and Hiehle 1949). If the results of large-scale controlled experiments are consistently publicized it seems likely that a sufficiently large portion of the public can be convinced of biological truths so that research can become an effective guide to policy. The failure to interpret findings realistically or to publicize facts that run contrary to existing operational procedures probably accounts in part for the regular recurrence of unsound public demands.

It is well established in wildlife science that animal populations are productive only in favorable environments. Controlling conditions on the land, especially in terms of the vegetation pattern, undoubtedly is our best key to management. Yet it is an unfortunate fact that pheasant requirements are so poorly understood that for most areas land improvement specifications simply can not be drawn. The research man may prove that artificial stocking does not pay, but he is in the somewhat unsound position of not being able to furnish a workable substitute. This is not completely so everywhere, since cover certainly is one obvious need on the prairies, but for most of the nation's pheasant range there is little that can be advocated with assurance.

It is consistently true, I believe, that *large* pheasant populations are produced only on fertile soils and that practically always they have access to the crops and early plant successions of cultivated areas. If these are requirements, they are difficult to build to order. We may come to a future acknowledgment for this species that good habitats largely exist but are not made.

The reasons *why* pheasants thrive on fertility and *why* they are restricted to certain regions are basic questions that research of the type done in the past 20 years has hardly begun to answer. Investigations into the physiology, nutritional requirements, breeding intolerances, and other inherent characteristics of the organism will provide a basis for interpreting the more superficial data now being gathered. State surveys, kill records, sex and age ratios, brood counts and food habits studies all are necessary and significant, but a much more fundamental knowledge is essential to an understanding of what counts in pheasant management.

We have had a scattering of exploratory and specific studies in the field of pheasant physiology, among which can be mentioned the experiments begun by Gerstell (1938) and Latham (1947)

in Pennsylvania, those of Long (1948) in New York, Shick (1947) and others in Michigan, and the investigations of Kirkpatrick (1944), Kabat, Buss and Meyer (1948), Thompson and Baumann (1950), and others in Wisconsin. No one has yet defined the minimum nutritional requirements of pheasants, and there are critical gaps in existing information on reproduction.

As suggested earlier, excellent use could be made of more detailed data on the habits, affinities, and regionally adapted varieties of pheasants on their native continent. It is entirely possible that there are other stocks than those we now have which could extend the range of the bird in this country. However, the best approach to this is to determine just what factors are responsible for confining the species and then find a solution after we know what the problem is.

What I am urging specifically is that more "pure science" be infused into the pheasant research program. A welter of relationships must be unraveled, and many issues will require controlled experiments on captive birds. Some such analytical work will be long-term in character. The application of facts will not be immediately evident. It will be unspectacular. But we are waiting for it, and agencies concerned with the production of annual crops of pheasants can well afford to carry a limited amount of such work along with the empirical cover-and-food type of study that gets a more ready public acceptance.

After a slow start, the population dynamics of pheasants are getting gratifying attention. Refinement of techniques is of particular importance and several excellent recent advances have been made. The reference tables for dating nesting events as constructed by Thompson and Taber (1948) should be widely useful. Kimball (1949) has described a type of crowing cock census that probably will replace the relatively inefficient roadside census as a means of getting extensive population indices. Island research has been particularly productive of significant population information. The work of the Oregon Wildlife Research Unit on Protection Island and Eliza Island has been notable (Einarsen 1945; Scott 1948) and on Pelee Island Stokes is gathering what will undoubtedly be the most revealing set of population statistics that has yet been available for study. This investigation at Pelee should be kept going indefinitely, since the island certainly is the most rewarding pheasant laboratory yet discovered.

The extent to which it is possible to elaborate and intensify pheasant research will depend upon the extent to which it is given necessary economic support. The administrator who wants imaginative and productive research will need to provide for the continuance in such work of able men with long training. This means paying for technical knowledge and research ability on a scale comparable to that of administrative responsibility. A few such positions give continuity to investigations and insure proper training for subordinates. Incompetent research is considerably worse than no research at all, since it embarrasses sound programs and spreads confusion far beyond its own bailiwick.

Since so many states now have pheasant research in progress, there are mani-

fest possibilities for overlap and unnecessary duplication. The need for more rapid exchange of information and the desirability of coordinating investigations nationally have been discussed at recent regional meetings. At the North American Wildlife Conference in 1948, Kimball (1948) called attention to "... the need for a coordinated regional pheasant research program wherein theories and ideas would be correlated and techniques of obtaining uniform basic data would be developed and standardized."

Most of the present discussion has hinged on the activities of states, and with good reason. The federal government has had no pheasant research program as such. It is with a realization of this deficiency and a recognition of the need for regional studies that Fish and Wildlife Service gamebird investigations now are being enlarged to include the biology and range requirements of pheasants. The leader of this project should be able to bring to research on this species something it has largely lacked heretofore—a nationwide perspective. He will keep in close touch with work being done in the various states and design his own research to fill in the gaps. Entirely on an informal basis, he will attempt to promote cooperation and a more rapid exchange of information among workers in this field.

During the past two decades, funds allocated to pheasant research have been far from commensurate with total expenditures for this species. The total effort has not been great, and much of the work has been done by young men just beginning their careers as wildlife biologists. As their experience grew, they were lost to research because their economic necessity had also grown. This probably is the most important reason why we have not had more progress in investigations of our particularly difficult pheasant problems.

As of the present, we know that the ringneck can tolerate a wide range of conditions, and we have not yet learned what really is essential. This ignorance is reflected directly in the primitive state of applied management. In terms of the progress now expected in any branch of scientific endeavor, it is doubtful whether we are more than 20 years removed from the measures practiced by Kublai Khan. Except for the advent of the electric incubator, our status would be in even greater question, since Kublai Khan had one major advantage: He was in a position to manipulate the supply of hunters at least as easily as the supply of game.

If we were to formulate a "10-year plan" for the cooperative improvement of pheasant research on the part of all agencies, state and federal, it probably would involve the following points of departure:

(1) Administrative recognition of the complexity of pheasant management problems and the need for supporting a high-quality sustained research program.

(2) Where possible, studies should be carried out on a *research team* basis. This would include well-trained and seasoned supervisory personnel and at least part-time service by specialists as need arose.

(3) The inclusion of long-term basic studies on physiology, nutrition, and reproduction, and sample-area experimentation for the improvement of habitats.

(4) Regional conferences for all personnel in pheasant work, to be held annually with at least one full day devoted to discussions of research and management.

(5) Interstate travel by field personnel to permit inspection of projects, comparison of techniques, and cooperative planning of programs.

(6) Free interchange of reports and publications among all agencies concerned.

Such an approach is suggested only for the federal government and those states with sufficient resources and with a sufficient stake in the management of this species. With participation by all interested agencies it is likely that 10 years of concerted effort would bring about more effective and realistic management in areas that can produce pheasants. A 10-year period would not produce the answers to all problems, but it might be the proper interval for reappraisal and, perhaps, for the publication of a book summarizing progress.

This review of the pheasant program probably can serve as a critique of wildlife investigations in general. In no other field of science have we taken research so lightly. Basically, this probably is an important reason for evidences of amateurism, inattention to fundamentals, and the want of a sound management philosophy. Immaturity can, perhaps, only be cured with time; but the process surely will be speeded by facing the issues and going to work on them.

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SOME SPECIFIC RELATIONSHIPS BETWEEN SOILS AND WILDLIFE[1]

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A major activity of the game research program in Missouri from 1942 to 1946 was a continuing study of the use of soil types as a basis for game census and range classification. The findings have been reported at North American Wildlife Conferences (Denney, 1944; Crawford, 1946) and recorded in the Federal Aid Reports to the Missouri Conservation Commission (Nagel, 1943; Anonymous, 1946). However, the results of concurrent observations and short-time projects regarding evidences of specific relationships between soil fertility and the quality, as well as the abundance, of wildlife have not been published. This report summarizes the findings by Nagel with regard to such relationships reflected by raccoons, muskrats and opossums and the findings by Crawford, Rowe and others, in rabbits and squirrels.

Soils and Raccoon

Analysis of county-average weights of 8,180 raccoon taken in the 1941 and 1942 open seasons, comprising 21 per cent of the total harvest in Missouri showed considerable variations in different parts of the State. Statistical treatment of the data showed that, regardless of sex and age differences, a definite relationship became obvious when the county-weight averages were plotted against county soil fertility ratings (Figure 1). The county soil fertility ratings were described by using a sliding scale (high 0.0–low 8.5) based on the average productiveness of the counties. Data for the derivation of the sliding scale on fertility ratings were collected by the College of Agriculture, University of Missouri. In preparing the statistically fitted curve, data from 89 counties were compressed into eight soil fertility groups in descending order from highest to lowest.

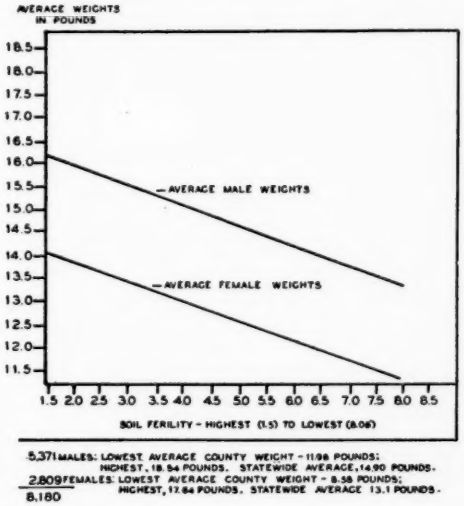

FIG. 1. Raccoon relationships between soil fertility and the average weights of raccoon harvested in 95 Missouri counties during the open season of 1941 and 1942. Fitted straight-line curves.

A similar influence is apparent in considering the distribution of approxi-

[1] Contribution from Pittman-Robertson Wildlife Research Project 5R of the Missouri Conservation Commission.

mately 39,000 raccoons comprising the total harvest (Figure 2). That the extent of the harvest by regions fairly reflects the population densities is corroborated by the soil type studies referred to above. Therefore, the curve in Figure 2 may also be considered as acceptably representing regional population.

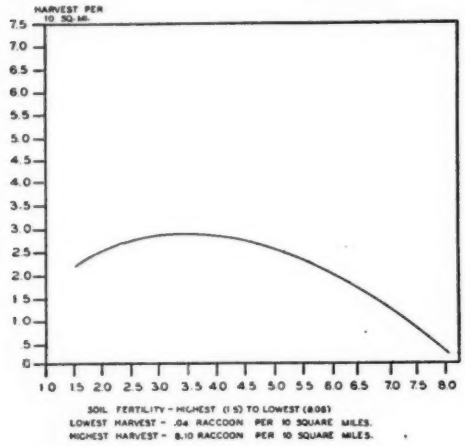

FIG. 2. Raccoon relationships between soil fertility and the average raccoon harvest per 10 square miles in the years 1940, 1941, and 1942. Statistically fitted curve. Based on data from approximately 39,000 raccoon taken in 114 counties.

The effects of intensive and widespread cultivation—in itself an indicator of fertility—in the most fertile region is reflected in a lower availability of raccoons. The height of the curve in relation to regions where fertility is still fairly high may be considered an expression of adequate fertility plus a type of agricultural use which permits the retention of a moderate amount of food and cover. Finally, the significance of the occurrence of the fewest and smallest raccoons in regions of lowest fertility cannot be discounted, particularly in view of the fact that permanent cover and water are most abundant and extensive in these regions.

SOILS AND MUSKRATS

Not enough muskrat weights were available to permit correlation with soil types. However, tests with factors of pelt size and quality revealed that these criteria also reflected variations, when related to the fertility of the soils contributing to the habitat.

The Meramec River watershed in east-central Missouri was used as a trial area, and the streams it contains were ranked into five types on the basis of fertility. The soils of the watershed are such that the presence of any alluvial soil at all in the stream areas, as well as its quality, must be considered. The streams then grade from the clear, relatively sterile spring-type flowing through and bounded by rock and gravel, to the more sluggish and turbid type with frequent mud-bottomed pools and soil banks. In fact, turbidity alone is a fair basis for ranking to show fertility gradations. The size factor of the pelts from each stream type was calculated from square inch, surface area measurements, and the quality factor from skin thickness and the length, density, and color of the pelage. A numerical measurement of the average of these factors for each group was developed. A total of 219 pelts was used. All pelts from all areas were examined during a five-day period.

When the stream types were arbitrarily ranked in order of turbidity, and the group quality factor for pelts from each stream placed opposite, definite and corresponding gradation was evident, from smaller and inferior pelts produced in the clear, almost sterile

TABLE 1.—OPOSSUM PELT SIZE AND SOIL REGION RELATIONSHIPS

Area No.	No. of Pelts	Size Factor	Pelt Size Rank	Typical Soil	Soil Fertility Rank
26	74	141.6	1	Union	1
27	222	132.5	2	Clarksville Gravelly	2
24–32	103	125.0	3	Lebanon and Hanceville	3

streams to the largest, best quality pelts in the more fertile types. There was one interesting and significant exception: A group of pelts from one fork of a low-turbidity stream ranked higher than a group from the other fork. Investigation showed that the entire head of the first fork was utilized as a commercial trout hatchery, and the channel served to drain off all the attendant organic wastes. This fertility is also strikingly evident in the superior size and abundance of minnows and aquatic plants which the stream below the hatchery supports.

Considering that conditions in a stream are the resultant of the quality and use of the land in the watershed, the logical implications of these data point out a practical effect to be anticipated of good watershed management, including fertilization, upon the quality of the muskrat harvest.

SOILS AND OPOSSUMS

A similar study was made of 399 opossum pelts during the same period. In ranking three sub-watersheds on the basis of soil fertility, a relationship between the size-quality factor of the pelts and the fertility rank of the corresponding sub-watershed was found, to the extent that the more fertile areas produced the largest and best quality pelts.

The manner in which the size of the pelts reflects the fertility of each region is shown in Table 1.

One hundred and forty-two opossum pelts were evaluated to show the relationship between pelt quality and the fertility of a watershed area. Data illustrating this relationship are shown in Table 2.

SOILS AND RABBITS

Weights were collected on 175,861 live-trapped cottontail rabbits (Rowe, 1941) from fourteen widely scattered parts of Missouri in 1941. These averaged 2.42 pounds per rabbit, January weights. Closer inspection of these records reveals considerable variation in the rabbit weights in different parts of the state. This variation ranged from an average low of 2.1 pounds at Eldon,

TABLE 2.—QUALITY OF OPOSSUM PELTS IN RELATION TO FERTILITY OF WATERSHED AREAS

Watershed	Soil Fertility Rank	No. of Pelts	Extra Heavy		Heavy		Medium		Light		Fur Quality Rank
			No.	%	No.	%	No.	%	No.	%	
Bourbeuse	1	74	2	2.6	24	32.4	46	62.4	2	2.6	1
Meramec	2	18	—	—	2	16.7	15	83.3	—	—	2
Dry Creek & Courteois	3	50	—	—	2	6.7	44	88.0	4	8.0	3
		142	2	1.4	29	20.4	105	73.9	6	4.3	

TABLE 3.—WEIGHTS (JANUARY) OF LIVE TRAPPED COTTONTAIL RABBITS COLLECTED IN 14 WIDELY SCATTERED POINTS IN MISSOURI

Collection Station	Number of Rabbits	Average Weight in Pounds
Eldon	3,024	2.1
Pilot Grove	13,320	2.2
Sedalia	11,196	2.2
Otterville	16,824	2.3
Smithton	2,880	2.3
Poplar Bluff	864	2.3
California	21,414	2.4
Syracuse	18,256	2.4
Tipton	16,514	2.4
New Hampton	2,000	2.4
Clinton	43,300	2.5
Neosho	13,752	2.6
Blythedale	1,020	2.7
Rutledge	9,500	2.8
Total	175,864	Avg. 2.42

in southwest Missouri, to a high of 2.8 pounds at Rutledge, in northeastern Missouri, which represents an average of 33⅓ per cent difference between the two localities. Other weights varied as much as 12½ per cent in one county.

By spotting the weight records on a soil map of the state, a relationship between the quality of the soil and size of the rabbits was immediately apparent; the heavier rabbits were associated with areas where grain yields are large, and the smaller rabbits were associated with less productive areas.

This association between soils and rabbit size was so significant that it was decided that a sample of rabbits should be collected from each major soil type of Missouri, in order to determine further physical and chemical differences. Approximately 450 animals were collected on 38 soil regions for study. From these specimens, skeletal measurements were made, and samples of tissues were collected for examination.

In physical measurements made of the femur bones, it was found that the bones taken from the rabbits on the better soils were up to 12 per cent larger (diameter, thickness of bone walls and length measurements) than those taken from rabbits on the low fertility soil regions.

Femur bones were also subjected to breaking tests on engineering testing machines, and measurements were made on bone weights, volumes, and specific gravity ratios.

A summary of these measurements is shown in the following table.

All femur bones taken in the high fertility soil regions of Missouri showed

TABLE 4.—SUMMARY OF PHYSICAL PROPERTIES OF 450 COTTONTAIL FEMUR BONES, COLLECTED FROM HIGH FERTILITY, MEDIUM FERTILITY AND LOW FERTILITY SOIL REGIONS IN MISSOURI

Soil Quality*	Avg. Weight (gms.)	Avg. Length (cms.)	Avg. Thickness of Bone Walls (mms.)	Avg. Maximum Diameter (cm.)	Avg. Breaking Strength (lbs.)	Avg. Volume (cc.)	Avg. Specific Gravity
High Fertility	4.172	8.03	.82	.76	44.5	3.98	.854
Medium Fertility	3.841	7.87	.74	.72	36.7	3.48	.814
Low Fertility	3.403	7.32	.68	.69	27.3	3.21	.786

* Soil quality determined by calcium, nitrogen, phosphorus, potassium contents and crop yields.

TABLE 5.—BREAKING STRENGTH OF RABBIT FEMURS FROM VARIOUS SOIL REGIONS IN MISSOURI (450 SAMPLES)

Soil Quality	Soil Type	Breaking Strength (Pounds)	Av. Breaking Strength (Pounds)
High Fertility	Marshall Silt Loam	55.2	
	Knox Silt Loam	53.4	
	Shelby Loam (Dark Phase)	56.5	
	Grundy Silt Loam	47.5	49.4
	Summit Silt Loam	41.6	
	Shelby Loam (Light Phase)	45.6	
	Wabash Silt Loam	46.2	
Medium Fertility	Cherokee-Parsons Silt Loam	43.2	
	Eldon Silt Loam	36.4	
	Gerald-Jasper Silt Loam	40.4	
	Crawford Gravelly Loam	39.6	37.8
	Bates Silt Loam	40.0	
	Memphis Silt Loam	34.5	
	Lindley Loam	43.5	
	Gerald Silt Loam	40.4	
	Putnam Silt Loam	22.3	
Poor to Inferior Fertility	Clarksville Stoney Loam (Southeast)	26.5	
	Clarksville Stoney Loam (Southeast)	27.4	27.3
	Clarksville Gravelly Loam	30.1	
	Ashe Stoney Loam (Granite)	25.4	

superior qualities to those taken from medium and low fertility regions. The breaking strength of the femurs from the better grade soils (medium and high fertility) averaged 43.6 pounds; for the low fertility soils the average was 27.3 pounds—a significant difference of 16.3 pounds, or 37.4 per cent.

An analysis of these breaking tests showed one exception to the rule, that being the Putnam silt loam samples. This medium fertile soil type (Northeast Missouri), which is a silt loam with a definite hard pan, produced a series of cottontail rabbits that fell far below the standard physical measurements of rabbits from the other medium fertility soils. As shown in Table 5, the breaking tests of rabbit femurs from the Putnam soil type averaged 22.3 pounds. This figure is lower than any of the breakage figures for rabbit femurs collected on the inferior soil types.

Explanation for this difference in bone quality on the Putnam soil is difficult since the calcium and phosphorus in this type soil compares favorably with that in other medium fertility soils of Northern Missouri. In work by McLean, *et al.* (1944) using domestic rabbits fed on crops grown from this same Putnam soil, it was found that the femur bones had a porous quality as indicated by low specific gravity readings. Therefore, it is possible that the native cottontail reflects the same soil conditions as did the domestic rabbits in the controlled experiments.

Probably as a result of this poor bone structure and porous quality, the Putnam bone samples ranked lowest in strength of the entire group.

In the specific gravity tests, the bone data showed close correlation to soil conditions. As soil fertility levels increased, the specific gravity ratios of the

bones increased. (See Table 4.) The high fertility areas produced rabbit femurs with 8 per cent higher average specific gravity than the low fertility regions. This specific gravity data ties in closely with the breaking strength tests, each becoming greater with higher levels of soil quality. The Putnam bone samples mentioned above, showed poor specific gravity ratios, confirming to a degree, the reason for low breaking points of the femurs from this soil region.

Carrying the examination of rabbit femur bones one step further, chemical analyses were conducted. Calcium, magnesium, potassium, sodium, copper, iron, manganese, and strontium concentrations were determined from perchloric acid digested bone material by employing the Lundegardh flame method, using a Hilger quartz spectrograph. Phosphorus in the perchloric acid digested bone material was determined by means of a photometer balanced against calibrated standards.

As noted in Table 6, both the calcium and phosphorus concentrations in the bones decreased as fertility levels of the soil became lower. These results tie in closely with the data on bone strength, and since bones are largely three parts tri-calcium phosphate and one part calcium carbonate, little difficulty arises in appreciating the relationship of their physical properties to the amounts of calcium and phosphorus.

McLean, *et al.* (1944) working with domestic rabbits, found that the relative increased retention of calcium and phosphorus was much greater than the relative increased total in the bones. This suggests that, with few exceptions, a high difference in calcium or phosphorus retention in the body, other than the skeleton, would precede any great change in totals of these elements in the bone. Since this in turn suggests that bones are possibly synthesized at the expense of the remainder of the body, it would follow then that either shortages or surpluses of calcium and

TABLE 6.—CHEMICAL ANALYSES OF BONE, MUSCLE, AND LIVER TISSUES TAKEN FROM 450 COTTONTAIL RABBITS, COLLECTED FROM HIGH, MEDIUM, AND LOW FERTILITY SOIL REGIONS

Soil Quality*	Copper (Cu)			Iron (Fe)			Strontium (Sr)		
	Bone	Muscle	Liver	Bone	Muscle	Liver	Bone	Muscle	Liver
High Fertility	2.2	2.–	2.–	3.– 20	3–20	39.7	1.72	.3–	.3–
Medium Fertility	2.–	2.–	2.–	3–20	3–20	70.1	2.54	.3–	.3–
Low Fertility	2.–	2.3	2.8	3–20	3–20	116.7	2.83	.3–	.3–
Soil Quality*	**Sodium (Na)**			**Magnesium (Mg)**			**Manganese (Mn)**		
	Bone	Muscle	Liver	Bone	Muscle	Liver	Bone	Muscle	Liver
High Fertility	112.3	28.2	32.8	128.6	30.9	17.7	.22	.13	.45
Medium Fertility	102.9	22.8	38.4	143.0	24.3	14.8	.24	.15	.48
Low Fertility	98.9	25.2	47.2	123.4	23.8	20.5	.21	.21	.67
Soil Quality*	**Calcium (Ca)**			**Phosphorus (P)**			**Potassium (K)**		
	Bone	Muscle	Liver	Bone	Muscle	Liver	Bone	Muscle	Liver
High Fertility	568.0	—	—	186.0	—	—	71.8	152.2	171.1
Medium Fertility	526.0	—	—	156.0	—	—	69.3	117.8	171.4
Low Fertility	476.0	—	—	126.0	—	—	66.3	111.4	191.8

* Soil quality determined by calcium, nitrogen, phosphorus, potassium concentrations and crop yield.
All figures expressed in milligrams (Mg.)/2 gram sample.
(All samples were 2 grams in weight.)

phosphorus are reflected first in the body mass and only later in the quantity and quality of the bone.

By making application of the above information on wild rabbits, it might be possible to find specimens possessing excellent bones, yet having such a lack of calcium and phosphorus in other body tissues, that reproduction and common body functions might be greatly hindered. It has been shown by Smith and Albrecht (1941) that fecundity is very closely related to the available nutrition of an animal, particularly in regard to the available proteins and mineral contents of feeds as controlled by soil fertility.

In further study of the analyses of rabbit femurs, sodium and potassium were found to decrease steadily when associated with lower fertility levels. Among the trace elements, strontium was present in larger amounts from bones collected on the poorer soils, whereas manganese, iron, and copper remained fairly constant among the samples.

Carrying the study one step further, chemical analyses of other tissues, namely muscle and liver, were conducted. These data are also summarized in Table 6.

In the liver analyses, iron, copper, sodium, magnesium, manganese and potassium concentrations were highest in the samples collected from low fertility soils. The muscle analyses showed higher concentrations of sodium, magnesium, and potassium in the high fertility soils, whereas manganese and copper concentrations were higher in the low fertility samples. A few of the muscle samples collected from the low fertility soils in the eastern Ozarks showed slight concentrations of nickel, rhodium and silver. Though not considered biologically essential, it was not surprising to find some of these additional elements in the tissues. The soils of the eastern Ozarks have a very complex mineral composition, and ultimately some of this material finds its way into the various types of vegetation.

Aside from the data on calcium and phosphorus in the bone tissues, the significance or role of the other elements in the bone, liver and muscle tissues cannot be well interpreted. Since plant food is the basis of animal life, any major mineral nutrients or trace elements taken from the soil into the plant, naturally find their way into animal tissues, but it may be long before they are recognized as essential, beneficial, harmful, or entirely inert. From the standpoint of animal health, assessment of significance is sometimes obscured by the fact that physiological function may be quite different in plant and animal economy, and that, even when a particular element is important for all forms of life, the quantities present may have a very different significance for different forms.

The soil regions from which most of the lower quality rabbits in the study were taken, consisted largely of areas that are forested or were originally forested. This situation cannot be considered as unusual because forest soils present many problems for livestock production. Soils that are forested or were originally so, are in most cases relatively low in fertility when compared with prairie soils, and though providing an abundance of potash, they are badly out of balance with other less

prevalent elements that would enable the plants to make protein and big seed crops.

In animal husbandry, it has been repeatedly shown that with the application of lime, phosphate and other fertilizers, response by animals has been shown: (a) by their choice in grazing of the treated soils first; (b) by their greater gains or young animal growth on forages from fertilized soils; and (c) by better reproduction on treated soils.

With the evidence we have at hand on various wild forms including the rabbit, the response to fertilized soils appears to be much the same as domestic livestock. In making practical application of these facts, it is possible to increase population levels and quality of game species by raising fertility levels of the land, providing other habitat conditions are not allowed to deteriorate. Population curves on cottontail rabbits, plotted in relation to soil fertility levels in Missouri, show much the same relationships indicated by Figure 2.

SOILS AND FOX SQUIRRELS

In making a study of fox squirrel production in Missouri, average sizes of litters were determined by counts of young in nests and foetuses from shot animals. Correlating the possible effects of soil fertility and food quality on fecundity, some interesting data were found.

The investigation, based on 52 litters, showed that the average litters produced on the more fertile soils of the northern counties was approximately .5 of an animal more than the average litter produced on the inferior, forested soils of the southern counties.

Food of the fox squirrels on the more fertile soils is supplemented greatly with corn, and the nutritional value of food on the northern counties is undoubtedly superior to that afforded by the combination of nuts, acorns, buds, and fruits in the heavily timbered areas of the southern counties. Timber-inhabiting squirrels also appear to suffer severe food shortages when nut failures occur. The periodic nut shortages appear to show close relationship to the various levels over the years.

These and similar evidences of the effect of soil upon game populations and quality indicate the desirability of a deeper perspective regarding the intricacies of land-wildlife relationship. We are becoming increasingly aware of what good nutrition means to humans, domestic animals and plants—and wild animals are no exception. As studies continue to disclose facts, the knowledge will eventually form an even more substantial basis for the statement, "As our soil goes, so goes wildlife."

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CHANGES IN COMPOSITION OF GROUND WATER, SOIL FERTILITY, AND FOREST GROWTH PRODUCED BY THE CONSTRUCTION AND REMOVAL OF BEAVER DAMS[1]

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The erection of a beaver dam introduces certain changes in the environment and in the established mode of life. The killing of trees by impounded water is not the most serious, but the most conspicuous detrimental outcome. This often brings a request from the land-owner to the Conservation Department to have the beaver trapped and the dam removed (Salyer, '35; Hovind, '48).

Removal of the dam by dynamiting or other means involves another drastic modification of conditions, and produces still further consequences. The entire cycle affects the position of the ground water table, fertility of soil, rate of forest growth, and the status of game within the flowage area, as well as on adjacent lands. The aftermaths of flooding and subsequent drainage were investigated on several typical flowages in Marinette County, Wisconsin, during 1947 and 1948. A summary of observations and conclusions is presented in this article.

METHOD OF STUDY

Four areas selected for investigation were under water for intervals ranging from 5 to 11 years; the other three areas were inundated for undetermined periods. The time which elapsed since the drainage was effected by dynamiting or by natural deterioration of the dam extended from 2 years to 3 or more decades.

The study was initiated by a general floristic survey of each flowage. Then trenches were excavated in areas of different stages of drainage or plant succession, and changes in soil profiles recorded. Particular attention was paid to the ground water level and the presence of reduced compounds. Soil

[1] Publication authorized by the director of the Wisconsin Agricultural Experiment Station. This work was carried on in cooperation with the Wisconsin State Conservation Department.

[2] The writers acknowledge the assistance of G. W. Randall and R. S. Dorney in field and laboratory investigations.

TABLE 1.—SELECTED ANALYSES OF SURFACE AND GROUND WATER ILLUSTRATING THE EFFECT OF ARRESTED WATER MOVEMENT DUE TO DAMMING (MARINETTE CO., WIS.)

Description of Area Sampled	Depth to Ground Water Inches	t°F.	Reaction pH	Spec. Conductance Mhos 10^{-5}	Total Alkalinity ppm.	Free Dissolved O_2 ppm.	Redox Potential Eh:mv
Creek water	—	69	7.49	29.6	165.0	8.2	213
Sedge meadow near creek	16	58	7.20	35.0	211.0	1.5	160
Sedge meadow on sand with clay lenses	12	57	6.79	48.5	180.0	0.5	126
Wh. cedar on wood peat above flowage area	4	61	6.50	20.9	83.0	0.4	69
Dead bl. spruce on flooded area	18	55	4.98	5.1	None	Tr.	−95
Chlorotic sedges on flooded moss peat	6	56	4.23	6.1	None	None	−153
Aspen on sand bordering flowage	30	60	6.39	17.7	75.0	1.5	74

samples were collected from various depths for laboratory analyses. A number of samples of surface soils were used for greenhouse investigations of mycorrhizae. The determination was made of the chemical properties of the surface and ground waters. The effect of the altered ground water table on the growth of trees was studied on strip sample plots.

PLANT SUCCESSION ON DRAINED FLOWAGES

Following removal of the dam, the area is invaded by *Carex* spp. and related marsh plants. This vegetative cover increases the fire hazard and obstructs natural regeneration of forest trees. The results of this study indicated that the persistence of marsh plants is largely determined by the nature of underlying substrata.

On coarse sandy soils, sedges maintain possession of the area for only a few years, when they are replaced by aspen and paper birch. On the other hand, on peat or muck soils, sedge meadows may resist the re-invasion of the forest for several decades. The establishment of the original cover of swamp hardwoods and conifers on these soils is usually preceded by a slow encroachment of willow, tag alder, dogwood, and other moisture-loving shrubs. Plant succession on loam and clay soils occupies an intermediate position between the two extremes: sand and peat. The establishment of aspen on fine textured soils is usually accompanied by balsam fir.

CHEMICAL CHARACTERISTICS OF SURFACE AND GROUND WATER OF BEAVER FLOWAGES

In the study of the chemical characteristics of surface and ground water, samples were collected from creeks, ponds, and saturated substrata within the flowages and from the immediate neighborhood. The tendency was to obtain samples of water varying in the rate of surface or subterranean movement, and in the nature of saturated material. Results of the analyses are presented in Table 1.

The high total alkalinity and high

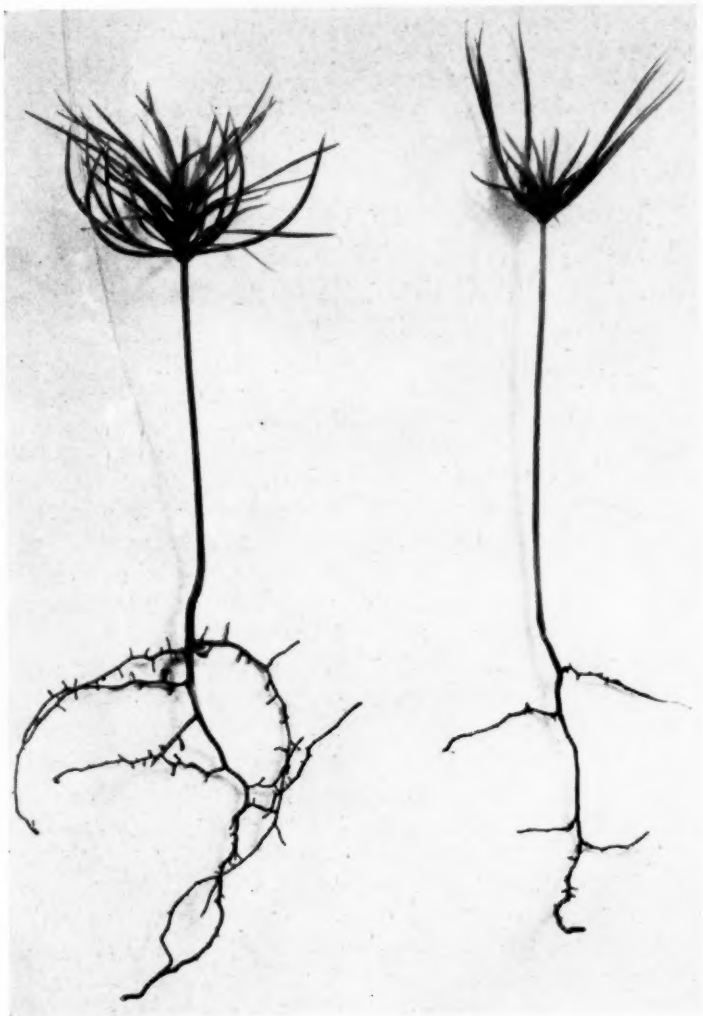

PLATE 2. Eight-week-old white pine seedlings raised on an upland soil (left), and on a soil which was under impounded water for a period of 9 years (right). Note the difference in the development of mycorrhizal short roots.

specific conductance of the rapidly moving surface and ground waters are undoubtedly due to their contact with lenses of lascustrine clay which occur sporadically in the glacial drift. Under the condition of stagnation, or sluggish drainage, the back water of the flowage acquires strongly acid reaction and loses most of its electrolytes. With practically no exceptions, the ground water of previously flooded lands was deficient in oxygen and possessed a low oxidation-reduction potential. *This indicates that the removal of the beaver dam drains the flowage only superficially, but not internally.*

Oxidation-reduction potential was found to be of particular value in the study of superficially or partially drained lands of beaver flowages because it expresses the over-all condition resulting from the combined influences of reaction, content of electrolytes, and oxygenation. The extremely low *negative* values of the redox potential reveal an environment favorable for development of anaerobic microorganisms whose metabolic by-products are highly toxic to other forms of life (Wilde and Randall, '49).

EFFECT OF IMPOUNDED WATER ON SOIL FERTILITY

The average results of analyses of several organic and mineral soils that had been submerged longer than 5 years are given in Table 2. These results conspicuously illustrate the effect of deoxidation and hydrolysis, the two principal processes which take place in flooded land.

From an ecological viewpoint, the most important outcome of deoxidation is saturation of the soil with toxic "swamp gases," including the ill-smelling hydrogen sulfide. The action of hydrogen sulfide on the ferric compounds enriches soil in soluble ferrous iron. Its content in some flowage soils exceeded the high level of 50 p.p.m. The accumulation of ferrous iron leads to fixation or "tie-up" of phosphorus in insoluble form. This is substantiated by the pronounced deficiency of available phosphates in practically all flowage soils analyzed. The extremely low base exchange capacity in mineral soils reflects the destructive hydrolytic action of water. In general, impoverishment of soil in available nutrients and its enrichment in growth-inhibiting

TABLE 2.—SELECTED ANALYSES OF SURFACE LAYERS OF PREVIOUSLY SUBMERGED LANDS INDICATING STATE OF FERTILITY FACTORS

Nature of Soil	Reaction	Exchange Capacity	Total N	Avail. P_2O^5	Avail. K_2O	Total Repl. Bases	Ferrous Iron
	pH	ME/100 g.	p.ct.	lbs./A	lbs./A	ME/100 g.	ppm.
Grey sand	5.19	2.6	.041	11.5	180	1.3	75
Grey sand	5.78	4.7	.108	34.5	90	2.7	15
Dark brown sand	5.89	6.3	.120	23.0	85	4.0	47
Dark brown sand	5.18	7.8	.210	66.0	168	4.4	25
Dark brown sand	6.78	5.5	.176	23.0	108	4.7	13
Sand over peat	5.81	2.9	.039	11.5	132	1.7	13
Wood peat	6.00	87.7	1.730	34.5	120	69.8	50
Wood peat	6.99	64.2	1.240	46.0	72	51.9	23
Sedge peat	6.58	112.0	1.400	34.5	180	84.2	27

substances are characteristic of flowage bottoms exposed by drainage.

The direct toxicity of hydrogen sulfide and the plasmolyzing action of ferrous iron may injure not only the roots of plants, but also the useful soil microorganisms. Because the growth of trees is intimately dependent on the activity of symbiotic fungi, the latter effect of toxic substances may be of far-reaching importance (Melin, '17; White, '41).

TABLE 3.—DEVELOPMENT OF MYCORRHIZAL SHORT ROOTS OF WHITE PINE SEEDLINGS RAISED IN UPLAND SOILS AND SOILS OF DRAINED BEAVER FLOWAGES

Nature of Soil	Soil Reaction pH	Av. Weight of Seedling grams	Damping Off p.ct.	Occurrence of Mycorrhizal Short Roots	Color of Seedlings
Upland sand	5.56	0.247	0.0	Abundant	Dark green
Upland sandy loam	5.61	0.227	1.4	Abundant	Dark green
Flooded sand	5.12	0.121	2.0	Sparse	Yellow-green
Flooded sand	6.78	0.180	16.6	Sparse	Yellow-green
Flooded sandy loam	5.89	0.101	8.5	Absent	Yellow
Infiltrated sand	5.18	0.132	0.0	Sparse	Yellow-green
Sand over peat	5.81	0.151	21.5	Sparse	Yellow-green
Woody peat	6.00	0.114	1.0	Absent	Yellow
Muck	7.51	0.122	46.7	Sparse	Yellow
Sedge peat	6.58	0.098	36.2	Absent	Yellow

SURVIVAL OF MYCORRHIZAL FUNGI ON SUBMERGED LANDS

To determine the effect of prolonged inundation on symbiotic microorganisms, samples of surface soils from different flowages were taken to the Griffith State Nursery greenhouse and sown to white pine. Several upland soils were also used in trials to serve as checks. At the end of the growing season, the seedlings were removed from culture pots, weighed, and examined for development of mycorrhizal short roots.

The results presented in Table 3 indicate that seedlings raised on upland soils produced well developed mycorrhizae, whereas seedlings raised on previously flooded soils showed only sparse and poorly developed short roots. On some of the latter seedlings the mycorrhizae could not be detected by microscopic examination (Plate 2). This suggests that the toxic substances generated in the soil by impounded water cause a partial destruction of mycorrhizal fungi. Therefore, until the soil is gradually reinoculated through the action of run-off, wind, birds, and animals, the absence of mycorrhizal fungi may be the major factor retarding the re-invasion of the drained flowage area by trees.

The ability of white pine to produce ectotrophic mycorrhizae at an early stage of development on normal soils should be pointed out. In this particular study distinct forked short roots were observed as early as eight weeks after germination.

RATE OF FOREST GROWTH FOLLOWING FLOODING AND SUBSEQUENT DRAINAGE

Impounded water produces the rise of the ground water table in adjacent

soils. Drainage of the flowage has the opposite effect. The influence of the altered ground water table on forest growth was investigated on strip sample plots transecting the areas adjacent to the flowage.

The determination of annual increment proved that the rise of the ground water table depresses the growth

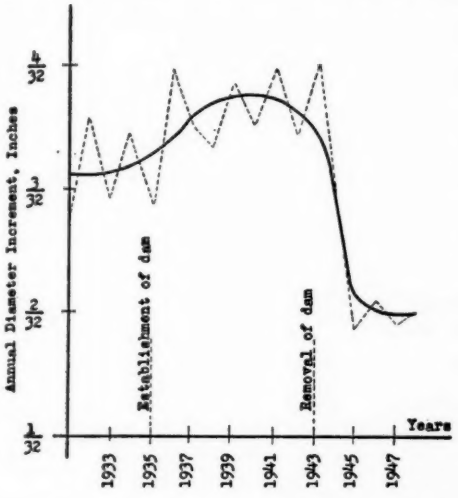

FIG. 1. Changes in annual increment of a 30-year-old stand of trembling aspen following establishment of a beaver dam and subsequent drainage.

of forest stands on neighboring lowlands, either by a partial "drowning" of the root systems or by decreased aeration of soil. On the other hand, the capillary action of the raised water table was found to benefit the growth of stands on neighboring uplands only to a limited extent.

When the dam is removed, the alteration of ground water causes still greater damage than flooding. This is because the rapid change in the ground water level creates danger of drought injury and generally decreases the growth of the affected forest stands on both upland and lowland sites. Figure 1 provides an example illustrating the changes in annual increment of an aspen stand following flooding and subsequent drainage.

CONCLUSIONS

Considering the problem of beaver flowages in its entirety, it appears to be more advisable to spend time and effort in preventing the settlement of the beaver colony in undesirable locations, rather than in removing the established dams. Preventive action, calling for a systematic observation of lands subject to beaver settlement, could be materialized through the close cooperation of game specialists, foresters, and land owners. Observation of stream courses would enable the timely logging of flooded timber, and thus greatly reduce financial losses. Aerial photography and periodic inspections of beaver inhabited areas by plane should greatly facilitate the task of beaver flowage management.

Aside from the ill effects on forest growth, draining of beaver flowages removes the climatically beneficial water reservoir, increases the fire hazard, and destroys the habitat of many fur-bearers. The negative effects of drainage are especially pronounced when the flowage land is made up of peat and muck. Therefore, in some instances, it may be advantageous to maintain the dam by inexpensive repairs even after the beaver colony has resettled elsewhere.

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BRANDING IN FIELD-WORK ON SEALS

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INTRODUCTION

During an extended stay on Sinclairs' Island, off the South-west African coast, where the life-history of the Cape fur-seal (*Arctocephalus pusillus*) was studied, efforts to mark seal induced experimentation along certain lines until finally branding only was resorted to as a means, among other things, of quick identification of certain individuals under constant observation.

Previous workers have used various marking systems, generally commencing with tagging and ending with the more drastic branding. Tagging included some form of metal strip stamped with a number and locked to the skin of the seal. Branding involved the application of hot irons when consecutive numbers were burned through the coat of the animal.

Early efforts at branding were seen in the Pribilof herd (*Callorhinus alascanus*) where various nondescript marks were applied to specific classes. Branded individuals confirmed age and identification assumptions (Osgood, Preble and Parker, 1915).

Lindsey (1937) describes how branding was adopted as a final expedient in marking individual Weddell seal (*Leptonychotes weddelli*) under constant study. Pups were not branded till over 44 days of age. The brand mark was "placed dorsally a foot or two in front of the tail. The number first was clipped into the wool with shears" (Lindsey 1937). A cow and pup received the same figures except in reverse order. The method enabled him to follow successfully the activities of some 243 seals during his stay in the Bay of Whales.

Sivertsen (1941), interested in the migrations and occurrence of the Harp seal (*Phoca groenlandica*), experienced considerable difficulty in capturing adult seal and was forced to mark pups only. The practical difficulties of branding under the adverse climatic conditions found in the White Sea area, necessitated other means of marking and aluminium-alloy discs, numbered and addressed, were fixed to flipper or tail. A red cross was painted on tagged animals to avoid their being slaughtered by the sealers.

Recently, the Fish and Wildlife Service, U. S. Department of the Interior, has conducted wide-spread tagging of fur-seal in an effort to learn more about their movements at sea.

Field-work on the Cape fur-seal, continuing over 1948, early demonstrated the need for proper recognition marks, and branding was considered routine work throughout the investigation. It is not yet known how the marks will survive successive moulting over a long period but it is hoped that they will be decipherable for several years.

TECHNIQUE

The Sinclairs' rookery is occupied throughout the year: lactating cows and their pups comprise the dominant class after the summer breeding season (November–December). Seal overrun the whole island which is about half a mile long and a few hundred yards wide. A high ridge, frequented by seal, runs lengthwise over the island, and shelters the houses accommodating the island staff.

The methods employed in catching seal were perforce guided by the demands of the investigation but serious curtailment was often experienced by the proximity of the herd and the ever-present tendency for the slightest disturbance to cause a wide-spread panic among the herd.

Tagging: Following the method of Sivertsen aluminium discs (about one centimeter in diameter) were devised and stamped with serial numbers only. Most of the thousand discs used were confined to black-pups, but several were attached to cows and yearlings.

Black-pups, caught on the rookery when a few hours old, were tagged on the posterior edge of the fore-flipper axilla, the wire connecting the two discs passing through the thin skin of the area and being locked beneath. Alternately, some discs were fixed to the tail in a similar manner. In all cases, the discs were eventually lost. Failure of the method was attributed to the type of tag used and the fact that mechanical abrasion is considerable when the young pups crawl about the rocky ground. The discs were scraped off flipper and tail. Among the adults marked, discs were also lost for the same reason.

Tagging involves the minimum of damage to skins, but as these considerations did not affect the field-work, this method, when its failure became evident, was immediately abandoned in favor of branding. The tags are of little value in providing individual identification-marks readily discernible from an "observation-hide" but they would supply considerable information about possible inter-rookery movements, foraging areas and general activities away from the rookery. The fact that they necessitated close inspection of the animal decreased their general usefulness.

Paint: Ordinary white oil-paint was smeared on certain tagged black-pups. The paint lasted fairly well until the pups began frequenting the pools at the rookery-edge. It proved satisfactory in locating these pups among a horde of others of similar age.

Branding: Branding was resorted to extensively as technique in handling the various classes improved. Over six hundred animals of various classes were branded throughout the year but these are merely a small fraction of a desirable quota of marked animals.

Apprehension in handling the big adults restricted large-scale branding till such time as the staff became more adroit at capturing and holding the in-

dividuals. Age groups demanded preferential treatment and the original staff of two was increased to three when more cows were marked. It was found that this number of personnel was most convenient for the work among the herd. Seal could seldom be captured without preliminary stalking and the technique of capture was frequently modified owing to the readiness with which the herd could be thrown into confusion. Elaborate precautions had to be adopted and the presence of non-essential personnel only added to the difficulties of a surprise approach. Animals were usually selected indiscriminately on the outskirts of the herd or in isolated places far removed from the others. Particular individuals could rarely be captured without causing a minor disturbance.

Yearlings could generally be approached easily, especially when clusters of this class were lying sound asleep on the ridge. Nets or sacks could then be cast over particular animals which were rapidly "bagged" and removed from the area for branding. On one occasion a long net was strung across a pathway down to the water's edge but the few adults among the stream of frightened yearlings broke the net so thoroughly that the method was discontinued immediately. Netting was also tried when black-pups were required in March and April but the labor of netting and disentangling the imprisoned animals discouraged further efforts in this direction. A sufficiency of these pups could be obtained on the rookery itself.

Cows were captured whenever opportunity permitted. During the breeding season ease of capture expedited the branding of many adult females but ordinarily catches were limited and frequently old decrepit cows were all that could be caught.

With the establishment of territoriality, the stabilizing effect of the harem bull and the disinclination of the cow to leave her newly-born pup minimized disturbances and often made possible the selection of particular cows for branding. Cows generally varied considerably in strength and temperament. Weighing nearly three hundred pounds, they could frequently be handled only with difficulty and proved more than a match for the staff on several occasions.

Bulls were rarely captured. Senile or "idle" males were all that could be handled. The chief difficulty experienced was the actual holding of the animals but those that could be apprehended were branded without trouble.

Initial efforts to capture and handle the cows were laborious and necessitated lassoing and bundling into large bags. This procedure was often dangerous and protracted and the activity and movement involved caused considerable disturbance among neighboring animals. Later, when the staff were more accustomed to handling the seals, these early efforts seemed ludicrous, although at first better technique appeared impossible. Cows trussed in the bag were removed from the main herd on a stretcher, and taken some distance for weighing and branding. It was found that such a lengthy operation frightened the cow who remained in the sea till nightfall and her pup would often be lost in the interim period. Gradually, as the staff became more skillful in handling the animals, it was found practicable for one man to

hold the lassoed cow at the end of the rope while another grasped the hind flippers and prevented undue movement. A third member of the staff branded the number in large figures on her back, noting this number and any relevant details about the animal in a note-book. This technique took a few minutes only and the cow could be released without trouble, to return straightway to her pup or the general herd.

The branding-iron was made of quarter-inch steel rod, slightly bent at the distal end. It was generally heated in a half paraffin-tin filled with live coals. This brazier was portable and could be carried about conveniently. Tins and irons were made from available scrap material.

The direction of the wind was an important factor determining observation and branding. The prevailing southerly wind meant that the bulk of the animals could be caught and branded on the north end of the island only. The faintest smell of smoke was sufficient to put the herd to flight.

Brand Marks: Originally miscellaneous typographical and other signs were branded on a few yearlings. It was soon realized that not only were these limited in scope but identification of the sign was not always free from error. In view of the fact that the animals were under regular observation, clarity of outline and uniqueness were essential.

Consecutive numbers were most practicable in identification and record-keeping. They were branded on the back in a posterior-anterior direction. Records contained details of weight, growth, moulting, successive captures, movements, and death.

Old brand marks were gradually obscured as new hair replaced the old and fell back over the denuded area. Thin or lightly-branded marks appeared as a dark stain on the new coat and were readily legible. It was often found desirable to retouch marks on the larger animals which were recaptured.

Effect of Branding: Surprisingly little effect was observed among the animals branded. It was originally considered that animals subjected to handling followed by branding would desert the area immediately, but this never occurred, and, indeed had this been so, the objects of branding would have been defeated.

The marks branded onto adults quickly healed, leaving a clear black outline. No cases of festering or irritation were observed. The mark was progressively obliterated by growth and replacement of the hairy-coat.

Among the black-pups, brand-marks tended to suppurate and a pus-filled scab covered the mark. This disappeared rapidly with the growth of the pup and it was only in the starveling or ill-fed pups that wounds were slow of healing. Among the yearling group, two instances of irritation set up by repeated rubbing, were noticed and the numbers partially obliterated as a result of this scratching. No lotion was applied to the burned area after branding. Usually the hair of the black-pups was burned lightly and the skin untouched: as the animals grew the marks were occasionally retouched and more permanently inscribed on the skin.

Objects of Branding: Some aspects of branding are worth noting. A knowledge of the daily and seasonal move-

ments of components of the herd was the main consideration and field-work was directed at establishing facts about individuals which could be recognized unequivocally. Studies on the herd and observations on individual seal, the case-histories of which were unknown, proved unsatisfactory and unzoological, and would only lead to erroneous deductions. Recognition marks were thus of prime importance and in the course of the work it was found that these had to be of such a size as to render them easily distinguishable among the dense herd. Fortunately location of specific animals was less difficult than expected on account of the general proclivity of most animals to return to the same area regularly after an absence at sea.

Attendance records, movements about the rookery, foraging in the adjacent waters, were all only possible through a knowledge of branded animals, and many generalizations about the habits of the herd could be avoided if specific animals were observed.

Only two examples of branded animals are given: In Plate 3A the cow is snarling at a black-pup shortly after she had lost her own pup. In Plate 3 B is a recently branded pup.

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A CANNON-PROJECTED NET TRAP FOR CAPTURING WATERFOWL

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A projection-type trap used in banding waterfowl was designed and built by the authors on December 1, 1948, on the Swan Lake National Wildlife Refuge, Sumner, Missouri. The trap and all accessories were made in the refuge shop and various problems in ballistics were solved in a series of field experiments conducted during the six-week period following completion of the first model. In its present form, this trap offers a practical and economical means for trapping large numbers of any species of bird tending to flock together. It is particularly effective for trapping waterfowl.

While the work at Swan Lake was done independently, rockets were used in England during the same year to project a net over wild geese. Peter Scott, in the First Annual Report of the Severn Wildfowl Trust (1948) reports that 31 white-fronts were caught in this manner. According to his report on this ingenious method, the rocket-propelled net is relatively slow, and for this reason, the catch comparatively small. The equipment used was costly,

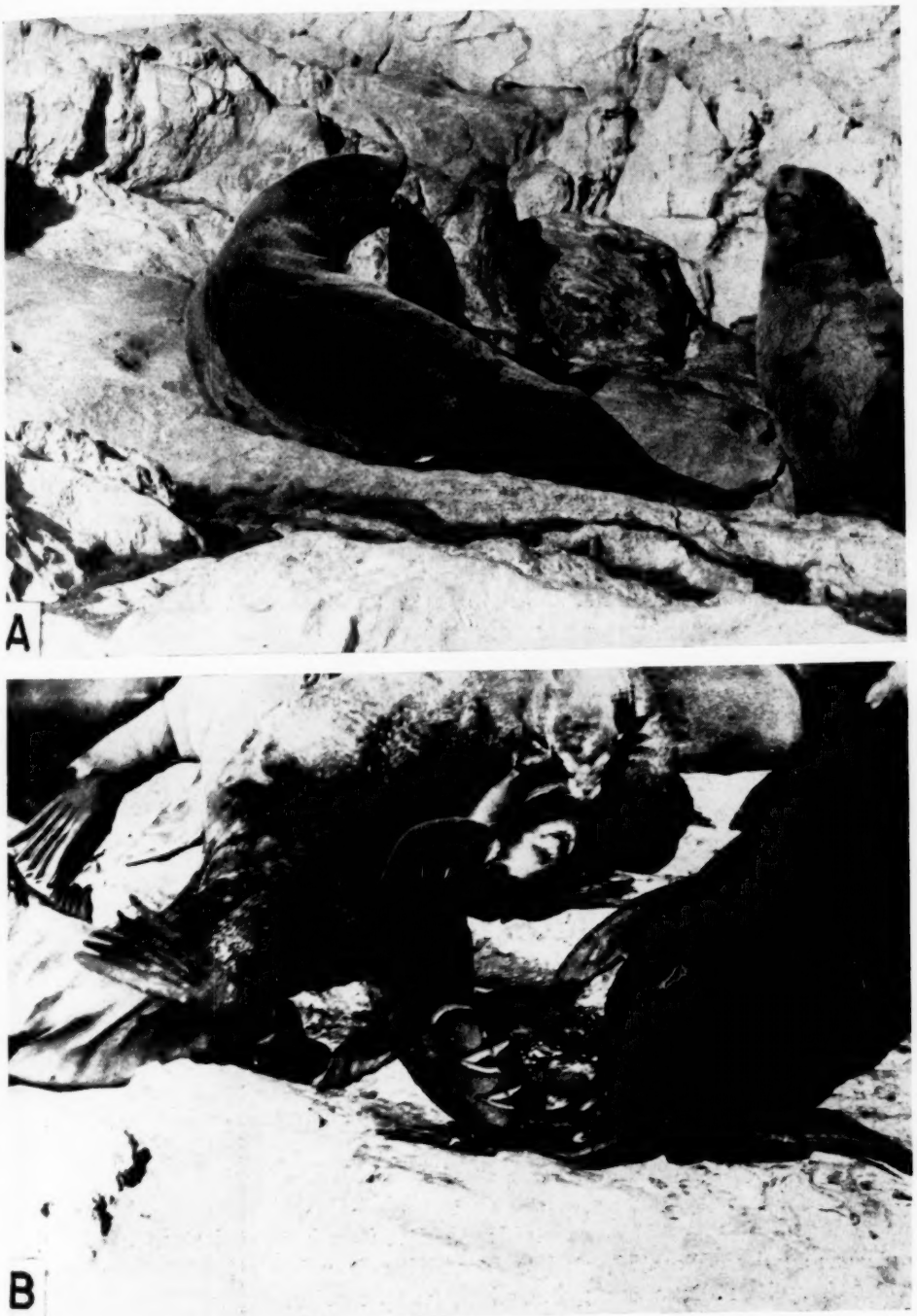

PLATE 3. A. Cow branded "251" snarling at a strange pup. B. Pup branded "442."

PLATE 4. A. A make-up of the projected-net trap in position for firing. White cords show the position of the leading edge of the net and three sets of attachments which extend to the rings on the projectiles inside the tubes. Co-inventor W. H. Thornsberry holds the trip-cord attached to the switch which is wired in series to the battery and tubes.

B. Part of a catch of 53 Canada geese made December 26, 1948. The geese have been banded and were under the net about 20 minutes before the picture was taken. They soon quieted down after being caught. Mallards captured in the trap struggled almost continually until released.

and tangling of the captured birds a drawback because the net had to be cut in order to release some of them. These difficulties have been largely overcome in our cannon-projected trap.

The trap (Plate 4) consists of a net measuring 25 by 80 feet with two and one-half inch mesh, of treated cotton twine. The edges of the net are laced with three-eighths inch manilla rope. The net, when dry, weighs approximately 40 pounds. By means of cords eight feet in length, three cylindrical projectiles are attached to the leading edge of the net. Each projectile is 2½ inches in diameter and 4 inches long, weighing five pounds. On the trailing edge of the net, two weights are attached, one at each corner, as drag anchors. An anchoring device which holds the trailing edge in position is sometimes superior to the drag anchors.

The projecting mechanism (Plate 4) consists of three seamless steel tubes. Each is 20 inches long with a 2½-inch inside diameter. One end is sealed with steel in which a hole 3/16 inch in diameter is drilled. A section of ½-inch rod is welded to the side which protrudes about a foot past the sealed end of the tube. This is sharpened on the end and when thrust into the ground serves to hold the tube in place at any angle desired. The propelling charge is made from equal parts (by volume) of potassium chlorate and granulated white sugar; approximately 6 drams of this mixture is used for each tube. The charges are sealed in moisture-proof cardboard containers 2½ inches in diameter and about ½ inch thick. The primer consists of a No. 6 electric cap which is placed inside the cartridge. The wires from the primer pass through the bottom of the cartridge and through the 3/16-inch hole in the bottom of the tube after the charge has been seated. The charges from the three tubes are connected in series to a 6-volt battery and through a weather-proof knife switch. A trip cord is run from the handle on the switch to the point from which the operator wishes to work. For use on the refuge, the tripcord-battery outfit is replaced by a hand generator with cable, which will serve at distances up to one-half a mile.

The development of the propelling charge confronted us with the most difficult problem we had to solve. It was desirable that the charge produce a relatively slow, pushing action with a minimum of noise. Also, it was required that this action be progressive rather than instantaneous. This indicated a slow-burning type of black powder. Most powders, however, are extremely susceptible to moisture and are quite noisy. We soon found that moisture accumulating from condensation in the tubes, when they were left out over night, ruined the charge. We then turned to a series of experiments with potassium chlorate, in combination with various hydrocarbons. This work eventually resulted in producing the charge in use made from equal parts of potassium chlorate and cane sugar. The components are merely stirred together, grinding being unnecessary and dangerous.

This charge has not only proved to be effective and relatively quiet, but it is reasonably safe to handle as well. The component parts may be stored in separate containers, a safety measure which is an advantage over the use of black powder. The primers, of course,

should be handled very carefully.

In setting the trap, the net is first laid flat on the ground. Starting at the trailing edge, it is folded in a pile 80 feet long by 2 feet wide with the leading edge in the center on top. The middle tube is then placed behind the net so that the open end of the tube is just above the back of the net and at an angle of 30 degrees above horizontal. The length of the tube is at right angles to the line of the net as it lies on the ground. The other tubes are then placed 18 feet on either side of the center tube at the same angle. These, however, are not aimed at right angles to the net, but are pointed 45 degrees away from the center tube. This will leave about 22 feet of the folded net on each side beyond the end tubes. Next, the propelling charges are seated in the tubes and a wad of soft paper (newspaper will do) corresponding to three sheets of $8 \times 10\frac{1}{2}$-inch typewriter paper, rammed firmly in on top. The projectiles are then seated on top of the wad and the lines to the leading edge of the net coiled to avoid fouling. Since these lines are only 8 feet long, and there now are 22 feet of net between the end tube and the end of the piled net, the leading edge of the net must be folded back again from each end so the projectile will reach the tube. After the projectiles are seated and the net checked, the electric primers are hooked in series with the battery or generator. The trap is then ready to operate.

When the operator completes the circuit, the propelling charges in all three tubes are activated practically simultaneously. This projects the 80-foot leading edge of the net into the air trailing the remainder of the 25-foot width. The point of aim on the two outside tubes overcomes the tendency of the net to drag in toward the center. This coupled with the retarding action of the two drag anchors on the back corners flattens out the net as it passes through the air so that when it reaches the ground it is spread evenly to its full extent. The net travels a total distance of from 10 to 15 feet, depending on whether it is dry and free from mud. Under adverse rainy conditions, it will travel about 10 feet. This travel, plus the full 25-foot extension of the net, gives a coverage of about 35 to 40 feet or 2,800 to 3,200 square feet. When projected, the net describes a parabola and reaches a height of approximately 8 to 10 feet, at which point it is fully spread. The projectiles are spent at that stage and drop to the ground, pulling the leading edge of the net down with them.

No attempt was made to catch a maximum number of waterfowl during the period the trap was experimentally operated. It was used cautiously and sparingly in order fully to determine its potential for causing injuries to the captured birds. Also, its use on a refuge required that we minimize as much as possible the amount of disturbance it would create.

Since we were particularly anxious to capture geese at the time, only two tries were made for ducks. After baiting 24 hours, the trap was thrown twice over a period of 48 hours from the same location and a total of 158 ducks were caught. The first try for geese was made December 10 and 20 were captured; since then two catches of 53 birds each were made. A total of 226 geese were caught in the first eight attempts. By

December 31, 1949, a total of 2,018 geese and 683 ducks had been banded at Swan Lake, by use of this trap.

In order that the disturbance factor might be fully evaluated, a baited area was established near the headquarters buildings a considerable distance from the nearest concentration of waterfowl. This was based on the premise that if the birds were unduly frightened through operation of the trap, they naturally would not return to this baited area. All of the eight successful attempts to catch geese were made from this area and a considerable amount of testing was done from the same spot in the course of the six-week period. We found that not only did the birds keep coming back, but quite often geese within 200 yards did not flush when the trap was thrown. In addition, four repeat takes were made, two of them within 10 days. From this, it is our considered opinion that the element of disturbance through operation of the trap is less than that created by the presence of people in the course of removing and banding the captured birds. The latter is unavoidable with any trap. In this connection the noise as a result of throwing the trap is less than that made by a 12-gauge shotgun.

In the course of capturing 158 ducks and 226 geese with this trap, one duck was injured. The condition bringing about the single injury has since been corrected. These facts point to an extremely low injury potential for the trap, in spite of the fact that it sends flying through the air projectiles of ample size and weight to do considerable damage should they strike a bird.

An important thing to consider is timing the throw of the net to avoid striking birds.

As the trap now operates, the initial thrust of the propelling charges places the net well out over the geese to be captured before they can fly. At this point the net is fully spread and the projectiles have spent themselves and start their relatively slow descent toward the ground. As they start to fall, all of the geese leave the ground; the ones under the net are pushed gently back and securely held down. The ones in the air out past the leading edge of the net merely pass the projectiles, offering very little resistance to them even if they strike. It must be remembered that the projectiles are now spent, and as with any object thrown up in the air, there is a momentary pause before descent and an acceleration again in direct proportion to the distance of fall. Assuming that the projectiles are 12 feet in the air at the time of this pause in trajectory, and with the goose now off the ground, the projectile falls only 2 or 3 feet before passing the escaping birds. During the early stages of the experiment we used longer cords from the leading edge of the net to the projectiles. We felt that this provided more of a safety margin, in that the projectiles would fall to the ground well on the other side of the flock to be captured. The opposite was true, however, as it slowed up the action of the trap and tended to pull the net through the flock after the birds had left the ground. In this way one duck was injured. For this same reason, the width of the net used should not be increased without increasing the velocity of the projectiles.

The location of the bait controls the position of the birds in front of the net

so that there is little danger of hitting them when the trap is first thrown. In other words, bait should not be placed directly in front of the tubes and should be out far enough to permit proper clearance. When the net is left folded in the open, the natural wariness of most birds (particularly geese) precludes their walking right up to it. We have noted that most geese remain at least 4 or 5 feet away. The operator should take care to see that the birds are in correct position before springing the trap.

The trap we now have was built at a cost of $21; however, a considerable amount of available salvaged material was used. Using new material, we estimate that it can be put together for $68. The cost of the more conventional Horseshoe Lake type goose trap of the large size is estimated at approximately $125, including labor. Inasmuch as the projection-net trap may be used for both ducks and geese, it is obvious that it is much cheaper. It has the advantage of being completely and easily portable.

The cartridges are prepared at a cost of approximately 12 cents each, making a total cost of 36 cents per throw.

From our experience with the net, we would say that it will stand up for two or more seasons of use. The principal wear is on the cords leading to the projectiles and on the cord laced into the leading edge of the net. These should be replaced each season.

The use of the projection-net trap also shows a saving in the amount of time required for operation. Most banding traps consist of a wire-netting enclosure, semi-permanent in location. Some are manually operated, using drop-rods and cotton netting along the sides, and others are automatic, depending on the birds' response to bait to overcome their natural wariness to the point where they will feed inside the trap.

For these reasons, the catch with an enclosure-type trap is made after a period of baiting long enough for the birds to get used to the trap. Even then, it has not been successful with certain species, since some are more wary than others.

The projection-net trap is readily and easily camouflaged and for this reason the birds feed within its range just as soon as the bait is found. Also, they will stay there a considerable period of time, which permits the operator to throw the trap more or less at his convenience.

The projection-net trap should be very useful in capturing large numbers of waterfowl quickly and efficiently.

A number of refinements can be easily effected with the present design whereby the weight is reduced sufficiently to permit carrying the entire unit as a back-pack. Flyway biologists, naturalists, and explorers could readily use such a trap and should find it of great assistance. Also, there are myriad other uses in the field of upland game-bird management for which this trap should prove efficient, with suitable changes in size.

Certain minor limitations have appeared in the course of the experimental work that should be noted. Tangling of the captured birds in the net is one factor that sometimes presents a problem. This can be reduced by using six or seven steel pins which are pushed in the ground through the edge of the net

after the trap has been thrown. This keeps the net stretched out flat and the birds underneath do not tend to ball themselves up as they do otherwise. Also, the wings may become fast in one or more meshes making it difficult to remove the bird from the net. Possibly a smaller mesh would improve this condition.

Mice or other rodents will gnaw the trip-cord and net unless they are treated with a repellent. It was found that a mixture of gasoline and asphalt when applied to the net was effective in preventing such damage. The gasoline evaporates, leaving the twine impregnated with asphalt which also serves as a water repellent. The importance of keeping the rodents away is illustrated by one occasion when the operator tried to throw the net and discovered that the trip cord had been neatly severed in eight places.

The trap should always be located in the field so that the operator's line of vision is approximately parallel to the folded trap. This permits a more accurate appraisal of the birds' position with regard to the tubes and the range of the trap. If desired, inconspicuous markers can be placed in the ground indicating the maximum throw of the net.

In wet weather a piece of waxed paper over the ends of the tubes is effective in keeping the water out without interfering with the operation.

CONCLUSIONS

The projected net trap promises to be the most versatile yet devised for catching waterfowl. It will operate satisfactorily in an open field, at the water's edge, or on ice. It is less selective than other traps, and should prove effective for capturing several species of waterfowl heretofore difficult to catch. Its portability makes it available for use in many locations where an enclosed type of trap is impracticable.

It can be built and operated economically, and, under favorable conditions, it requires less attention than many enclosed-type traps.

Plans and specifications for the construction of the cannon-net trap will soon be available for use by authorized persons, and may be obtained from the U. S. Fish and Wildlife Service, Washington, D. C.

A LIGHT METER FOR COVER-DENSITY MEASUREMENT*

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An entirely objective method of measuring cover density would help in the accurate appraisal of cover used by wild animals. Trippensee (1935) and Wight (1938) were among the first to seek such a method. Theirs was based upon the number of stems in a system of quadrats; it was tedious and also it ignored the upper parts of the plants. Wight described a target-board system that gives an accurate measure of density, but the equipment is too cumbersome for one person to use.

Plant physiologists and ecologists have long measured light intensities beneath various types of forest canopy (Morris, 1936; Miller, 1938; Bacon, 1939; Wright, 1943; Shirley, 1945). The present paper assumes that light intensity is a function of cover density.

The Instrument and Its Operation

Cushman (1933) and Miller (1936) described a light-intensity meter practical for field use, built along the lines of the one described in the present paper. A photograph, cutaway drawing, and wiring diagram of the present instrument are shown in Figures 1 and 2, and Plate 5A.

The instrument used by Cushman and Miller enclosed the photronic cell and microammeter in a single unit, while that used in the present study employed separate units. There is a distinct advantage in this: One can read the microammeter in the hand while the photronic cell is in the vegetation. To facilitate the reading of the microammeter, resistors are used, controlled by a three-position switch (Figure 1, Parts S, R_1, and R_2) to obtain three ranges: low, middle, and high.

The instrument is calibrated with a standard incandescent lamp, placed

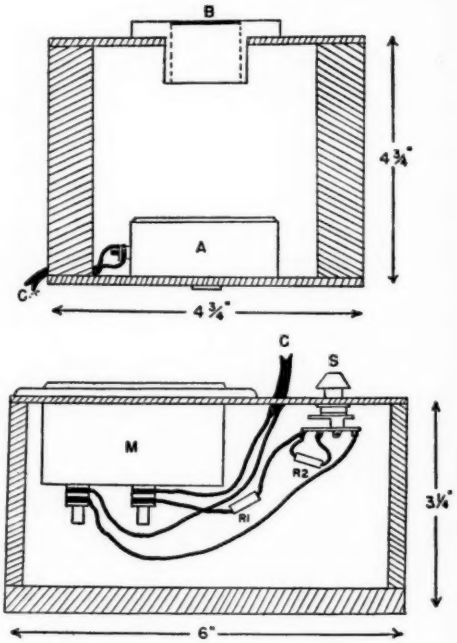

Fig. 1. Cutaway drawing of light meter. A. Photronic cell. B. Diffusing disc. C. Extension cord. M. Microammeter. S. Switch. R1 and R2. 1-watt radio-type resistors.

* Contribution from the Missouri Cooperative Wildlife Research Unit: U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, and University of Missouri cooperating. This paper represents part of a study conducted with the aid of a fellowship from the Edward K. Love Foundation.

directly in front of the photronic cell unit a known distance from the light-diffusing disc. Radiant energy is converted to electrical energy by the sensitive element of the photronic cell and is measured by the microammeter. Calibration graphs are constructed to convert microammeter readings to foot-candles.

The first instrument used in this study employed a photronic cell exposed to direct sunlight, like that used by Cushman and Miller. Rotation on a horizontal plane yielded erratic readings. Laboratory tests showed that not all parts of the sensitive element were equally sensitive, and that shadows cast by the photronic cell case upon areas of unequal sensitivity accounted for the erratic readings. Addition of a diffusing disc (Figure 1, B) removed the difficulty by eliminating shadows. All parts of the sensitive element then received light of equal intensity and the readings represented an average of all parts of the sensitive element. In the laboratory it was found that rotation of the instrument about an axis perpendicular to the diffusing disc brought no change in the readings. The disc served further to protect the cell from direct sunlight which, according to Wallace (1937), causes a photronic cell to become erratic and inaccurate. Under oblique illumination, the readings fell off somewhat more rapidly than would be expected from Lambert's Law.

The minimum size and number of quadrats needed for adequate sampling of a plant community were determined by the species-area curve method (Cain, 1938). It was learned that seven 1×4-foot quadrats would provide an adequate sample of the most complex types of shrubby and herbaceous cover on the area studied. This pattern was used at each station. The uniformity of data thus obtained made statistical analysis easier. With adequate sampling of the vegetative communities, it may be assumed that readings taken in the quadrats provide representative samples of light intensity within the vegetation.

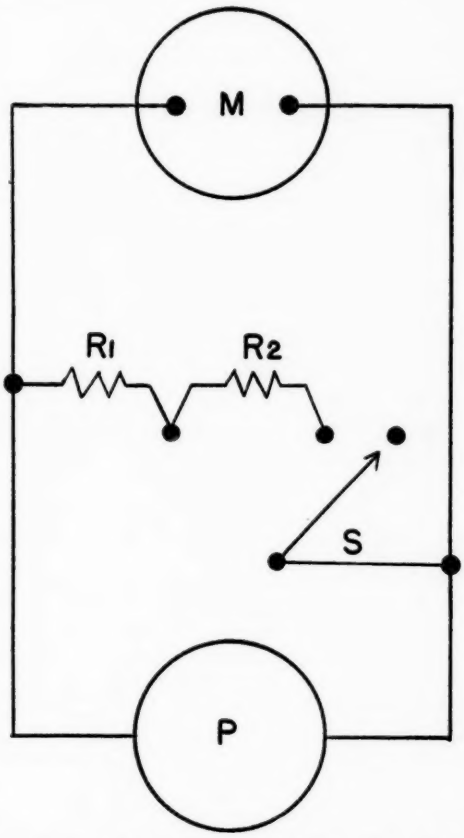

FIG. 2. Light meter wiring diagram. M. Microammeter. P. Photronic cell. S. Switch. R1 and R2. 1-watt radio-type resistors.

The procedure in making a reading was as follows: A station consisted of seven quadrats within vegetation of

similar life form (Clements and Shelford, 1939) and species composition. The quadrats were in the vegetation at points located by pacing. The number of paces between quadrats was constant for any one station, though it varied between stations because of the considerable variation in the extent of vegetative types of similar life form and species composition.

The phototronic cell unit was put down at five points: the four corners and the center of the quadrat. Two readings were made at each point, one with the unit horizontal, the other with the unit pointed directly at the sun. Miller (1936) and Wallace (1937) found the horizontal position the more satisfactory since it eliminates light reflected from the ground.

Upon completing the readings within the quadrat, a horizontal and a direct reading were taken in the open where there were no obstructions. The average value of the readings within the quadrat divided by that of the readings in the open gave the percentage of total sunshine for that quadrat. The station percentage was the average of quadrat percentages.

To obtain comparable data, Miller (1936) minimized the effect of solar ascension and declension by making his readings between 11:00 a.m. and 1:00 p.m. The writer also made all of the readings used for density determination between these hours (Standard Time).

It was impossible to obtain accurate readings under a broken cloud cover. The time elapsing between readings permitted great variation in intensity with cloud movements. Bacon (1939) had the same difficulty in measuring the percentage of total sunshine within forest stands. To eliminate it, he developed a light meter employing two photronic cells wired in opposition to each other. One could be placed in the open, the other in the vegetation, and the percentage of total sunshine was read directly on the microammeter.

Rather than introduce this extra complication, the writer confined his recordings to days when light conditions were constant. Comparable values for the percentage of total sunshine can be obtained on either clear days or days with uniform cloud cover. Bacon found little variation in percentage relationships under these conditions.

There is a clear relation between plant life form and amount of light penetration. Hence records of the predominant plant species at each station were kept to aid in the interpretation of light readings.

USE OF THE INSTRUMENT IN MEASURING COVER DENSITY

During the winter of 1948, light-intensity measurements were made at 34 stations, representing the major plant communities found on the study area. At each station, 70 readings were made within the vegetation and 14 outside it: 2,855 in all. The study area (2,070 acres) was a mile west of Ashland, 15 miles south of Columbia, Missouri. The land is rated by the U. S. Soil Conservation Service as Class V–VII, continuous cultivation and overgrazing accounting mostly for a run-down condition common to the poorer farmlands in this region.

Trees along the draws and branches make up most of the woodland, with oak and hickory predominating, and elm,

PLATE 5A. Light meter. (Left) Photronic cell unit. (Right) Microammeter unit.
PLATE 5B. A herbaceous fencerow having a total-sunshine value of 55%.

maple, and ash ranking next. Where the woodland is grazed there is a grassy understory, while shrubs, most commonly buckbrush (*Symphoricarpos orbiculatus*) and blackberry (*Rubus* spp.), are usually present in ungrazed woods. Scattered elm (*Ulmus americana*), persimmon (*Diospyros virginiana*), and sassafras (*Sassafras albidum*) are occasionally found in the fencerows; most of these, however, contain native shrubs and herbs, notably buckbrush and giant ragweed (*Ambrosia trifida*). Commonly associated with them are blackberry, wild grapes (*Vitis* spp.), smooth sumac (*Rhus glabra*), poison ivy (*Toxicodendron radicans*), nodding wild rye (*Elymus* spp.), tall goldenrod (*Solidago altissima*), gray goldenrod (*S. nemoralis*), bluegrass (*Poa pratensis*), beggar-ticks (*Bidens* spp.), sunflowers (*Helianthus* spp.), and fleabanes (*Erigeron* spp.). The stages in revegetation of abandoned cropland here are similar to those described on a nearby area by Drew (1942).

The data were treated statistically by analysis of variance (Snedecor, 1946), isolating the experimental error. Table 1 shows the results.

There is a significant difference between readings taken with the cell horizontal and those with the cell pointed at the sun. The standard error of the means is more erratic for direct readings than for horizontal readings, the latter being the more reliable.

There is also a significant difference in light penetration at different stations. By using the combined within and interaction as an experimental error, the variation in percentage needed at the 5% level to show that stations are probably significantly different is 7.64 (Hayes and Immer, 1942). Thus, if the precautions mentioned in the following paragraph are considered, it can be said that stations differing by no more than 7.64 points are probably similar in density of vegetation, though one out of 20 stations of similar density may fall outside that range.

TABLE 1.—ANALYSIS OF VARIANCE OF STATION LOCATIONS AND POSITION OF PHOTRONIC CELL UNIT

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Calculated F	F at 5% Level
Total	475	159,091			
Station	33	110,727	3,355	27.7	1.49
Position of Cell	1	1,430	1,430	11.8	3.86
Interaction	33	3,991	121	1.1	1.49
Within	408	42,943	105		
Interaction Plus Within	441	46,934	106.4		

Knowledge of the species composition of the vegetative community within which light readings are taken is necessary for correct interpretation of the total-sunshine values. One example in buckbrush had a total-sunshine value of 33%, while another in buckbrush, not overtopped by trees, had a value of 55%; yet the brush in the latter is

denser than that in the former, the discrepancy being due to the presence of a tree canopy in the latter. Light readings taken beneath a tree canopy tell little about the density of the understory; in other words, accurate comparison by the present method can be only between areas having similar canopy conditions.

Readings made among shrubs and herbs that are not bunch-formers probably indicate the density of stems at ground level as well as the density of the canopy. Readings made among bunch-formers indicate canopy density. The area beneath the canopy, except for the small area covered by the basal units of the plants, is open regardless of the values obtained. "Open" in this case refers to the density of stems at the ground surface.

Total-sunshine values in shrubs ranged from 43% to 68%, although there are undoubtedly stands elsewhere that would yield higher values. In herbaceous vegetation, the values ranged from 55% to 91%. As expected, herbs in fencerows yielded lower readings than those in fields, since the former are seldom cut in land of this type. An herbaceous fencerow dominated by giant ragweed, beggar-ticks, and fleabanes having a total-sunshine value of 55% is shown in Plate 5B. A field dominated by common ragweed (*Ambrosia artemisiaefolia*), beggar-ticks, and Korean lespedeza (*L. stipulacea*), had a value of 77%.

The light meter provides an objective measure of cover density, and also a training device for fairly accurate visual evaluation of cover. In using it, cover could of course be broken down into any number of density classes, but the results would be too complex for practical field use. Instead, the writer finds that satisfactory appraisals can involve only three classes: dense (0–50%), medium (51–75%), and open (76–100%). After some practice, the percentage of total sunshine at any point can be closely estimated visually. This is a useful field skill, and it can be kept fairly reliable by frequent instrumental checks.

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TRANSPLANTING BEAVERS BY AIRPLANE AND PARACHUTE

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For a number of years Idaho's Fish and Game Department has been transplanting beavers from areas where they exist in abundance and may be causing damage to irrigation systems, orchards, and other plantings. In territories to which they are moved beavers usually set up colonies, multiply, and establish important fur-bearing populations. In addition, they do much toward improving the habitats of game, fish, and waterfowl and perform important service in watershed conservation.

Sites which are to receive beavers are selected by Conservation Officers of the Fish and Game Department, after consultation with the state Fur Supervisor, and with local Forest Service officials. Live animals are delivered by the Regional Caretaker-Trapper, who is required to supply for this purpose 10 per cent of the total number allotted to him for pelting in any given year.

Experience has shown that young animals, preferably from one colony, transplant most successfully. They are less pugnacious than older individuals; they do not tend to migrate readily; and they will give more years of service than mature beavers. However, the sexing of young beavers is difficult. The best results have been obtained by planting four beavers at a time; usually one male with three females. However, when the animals on hand make that sex ratio impossible, it is best to plant two females with two males.

July and August seem to be the ideal months for transplanting beavers. Earlier in the year they tend to migrate; later in the year, and particularly at high altitudes, they do not have time to become properly entrenched before winter is at hand.

In those states which are well populated and comparatively level, or have many miles of back country roads, the transportation of live animals is neither difficult nor expensive. In Idaho, the mountains, heavily forested country, lack of roads, and generally inaccessible wilderness areas have complicated the beaver-transplanting program.

The former method of transportation was arduous, prolonged, expensive, and resulted in high mortality among the beavers. A typical schedule might be the following: Beaver were packed on horses or mules for several days, from

the locality where the animals were live-trapped, to the trapper's truck. After enduring a hot and dusty trip, they were delivered to a Conservation Officer. They arrived so late in the day that they must be held over night. Next day another truck ride was necessary to the end of the road nearest the site selected for planting. Once more they were loaded on pack stock and subjected to more handling, heat and jolting.

Beavers cannot stand the direct heat of the sun unless they are in water. During transportation they must be constantly cooled and watered. Sometimes they refuse to eat. Older individuals often become dangerously belligerent. Rough trips on pack animals are very hard on them. Horses and mules become spooky and quarrelsome when loaded with a struggling, odorous pair of live beavers. These problems involve further handling and too frequently result in a loss of beavers.

It was evident that a faster, cheaper, and safer method of transportation was a vital need. The use of planes and parachutes has filled that need.

Parachutes of various sizes and materials were employed during experiments with dummy weights. The most satisfactory results were obtained with a 24-foot rayon parachute of war surplus stock, procured from the Forest Service. The Forest Service was using a modified pack which travels right along with the 'chute. It is a heavy canvas sack in which any recovered parachutes may be replaced quickly without intricate folding, This parachute has a carrying capacity of 140 pounds. The box now in use, holding two live beavers, weighs between 80 and 105 pounds. Such a load is great enough to open the 'chute readily and keep the box securely shut during the descent, yet it is light enough to land very gently.

The first box tried had ends made of woven willow. It was thought that, since willows were a beaver's natural food, the animal would gnaw his way to freedom. This method was discarded when it was discovered that beavers might chew their way out of these boxes too soon, and be loose in the plane, or fall out of a box during the drop. Packing a pair of beavers in one box made it possible to halve the number of 'chutes used, and the cost of a double capacity container was not nearly double that of a single container. Also it was found that when two animals land at the same time there is less tendency for either to migrate immediately.

The box consists of two lidless boxes fitted together to open as a suitcase does (Figure 1). It is made of four-quarter surfaced lumber, #4 common grade. It is 30 inches long, 16 inches wide, and 12 inches deep, and weighs about 20 pounds. One-inch holes drilled through the walls provide ventilation. Two ten-foot lengths of half-inch sisal rope are fastened across the bottom, approximately 3 inches from the ends. These ropes are secured to both sides of the bottom with box nails, put through and clinched. The ropes thus act as hinges. The ends of the ropes are carried up each side, put through holes about 3 inches below the box top, and emerge through a second set of holes about 1 inch in from the outer edge of the box top. These holes are drilled at an angle from the outer and lower surfaces so that when the ropes are drawn

through and strain put on them, no binding or cutting occurs. The two ends of each of these sling ropes are joined in a square knot. Approximately 1 inch in from each sling rope, and crossing the bottom of the box but not fastened to it, is a heavy 2 inch rubber band. These elastic straps extend 3 inches up each side of the box, and are fastened there with fence staples. They are cross-sections of heavy duty truck tubes so that they form double spring hinges. Each band exerts about 10 pounds of tension, which is sufficient to snap the box open and free the beavers as soon as the much greater tension of the shroud lines is removed when the box lands on the ground and the 'chute collapses.

When two beavers are put into one of these boxes it is shut and the sling ropes drawn together at the opening. Two turns of four strand linen cord are wrapped around each of these joinings, and tied with a surgeon's knot. This lashing is quite strong enough to prevent the box's opening during loading or flight, but the shock which occurs when the box is tossed out of the plane breaks them. The weight of the loaded box is more than enough to keep the box closed during the descent.

The hook up for plane, parachute, and box, is described in the order of its arrangement. In the plane is installed an ordinary cargo dropping static line, usually from 6 to 12 feet of ½ inch manila rope, which allows the beaver box to clear the open door by one foot. To the end of this static line is spliced a heavy harness snap. The canvas bags for the parachutes have draw strings at both top and bottom. At the top of the pack, and affixed to the apex of the

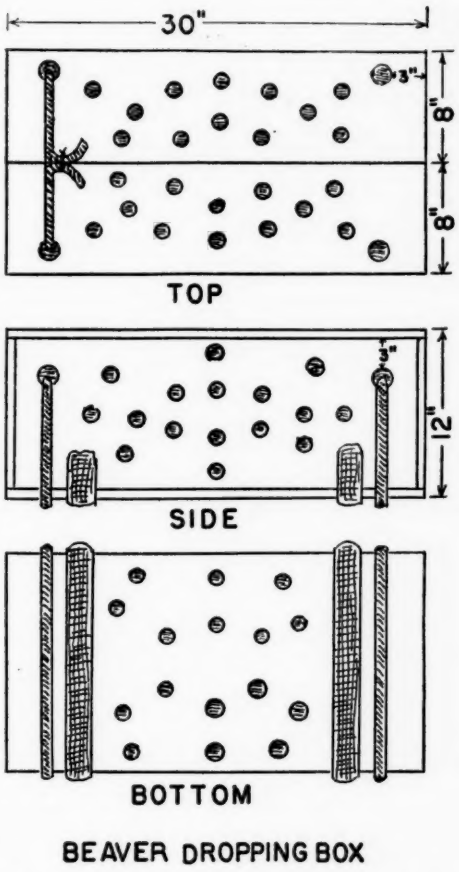

FIG. 1. Diagram of box in which beaver are dropped by parachute.

chute by two turns of eight strand linen cord, is a sturdy harness ring. One long piece of six strand linen cord is laced back and forth through the grommets at the mouth of the pack, and should be passed through the harness ring at least twice. This lacing, which is broken later, is used instead of a drawstring to hold the pack securely closed. The ends of the shroud lines at the bottom of the pack are fastened to a three-foot length of 1½ inch heavy canvas webbing. To one end of this webbing

strap is sewn a harness snap, and to the other end, a D-ring. It is this webbing loop, passed through the upper bights of the two sling ropes on the box, and its ends snapped together, which holds the box during the drop. When the box is thus secured to the shroud lines, the snap at the end of the static line is hooked into the ring affixed to the 'chute's apex, and everything is ready for the drop.

When the box is tossed out, the initial shock breaks, first the sling rope lashings, and then the cord holding the pack closed. The 'chute is drawn rapidly out of its pack and, when the whole hook up becomes taut, the final strain breaks the eight strand cord holding the 'chute's apex to the harness ring on the static line. The 'chute opens quickly, and the whole operation takes only a few seconds.

In our operations a Travelair was used, which carries pilot, Conservation Officer, and eight crates of beavers. The targets chosen are usually small, open meadows through which the selected streams run.

The best altitude for launching is between 500 and 800 feet. This height assures sufficient time for the 'chute to set the box down gently. Yet, it is low enough for accuracy in placing the box in the selected meadow, and to avoid trees or other obstacles in which the 'chute and box might become entangled.

Satisfactory experiments with dummy weights having been completed, one old male beaver, whom we fondly named "Geronimo," was dropped again and again on the flying field. Each time he scrambled out of the box, someone was on hand to pick him up. Poor fellow! He finally became resigned, and as soon as we approached him, would crawl back into his box ready to go aloft again. You may be sure that "Geronimo" had a priority reservation on the first ship into the hinterland, and that three young females went with him. Even there he stayed in the box for a long time after his harem was busy inspecting the new surroundings. However, his colony was later reported as very well established.

In the fall of 1948, 76 live beavers were dropped with only one casualty. On the first drops, light weight lashings were used on the sling ropes, and one of these broke before there was sufficient tension from the shroud lines to hold the box closed. One beaver worked his head through the small opening thus made for him, and managed to climb out onto the top of the box. Even so, had he stayed where he was, all would have gone well; but for some inexplicable reason, when the box was within 75 feet of the ground, he jumped or fell from the box.

Observations made late in 1949 showed all the airborne transplantings to be successful. Beavers had built dams, constructed houses, stored up food, and were well on their way to producing colonies.

The analysis of costs of this method of transplanting beavers showed a marked saving. The expense of transplanting four beavers is approximately as follows:

Cost of two boxes	$ 2.00
Cost of two cargo 'chutes	16.00
Flying time for 1 planting	12.00
Total	$30.00

This reasonable cost is reduced in practice because packers, game de-

partment men, ranchers, and Forest Service employees pick up and return some of the 'chutes. Enough are returned in good condition to lower the cost per transplant to less than $16.00. The savings in man hours, and in the mortality of animals, is quite evident. Sex ratios are maintained. The beavers are healthier, and in better condition to establish a colony.

FISH AND SHELLFISH MEASURING DEVICES

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A great many investigators in the field of fishery biology are concerned with studies of marine or fresh-water populations of fish or shellfish and, consequently, much of their effort is devoted to acquiring a knowledge of the age, growth and racial characteristics of the species involved. Information on these problems is largely obtained from measurements of the various parts of the bodies of the organisms. Differences between the age, growth and morphological characters of various populations or races of a species are often small; therefore, it is usually necessary to employ relatively large masses of data to establish whether or not a significant dissimilarity exists. Because of the need for measuring large numbers of individuals, fishery biologists have devised a number of instruments which enable them to collect linear measurements in both an accurate and facile manner.

I have been prompted to discuss this matter of measuring fish and shellfish by the reading of an article by Hiatt and Hamre (1945) in which a description is given of a measuring device which has been used in an improved form by fisheries men both on this continent and in Europe for many years.

It is, of course, always difficult to determine the original inventor of any device. Many ingenious devices have no doubt been used for specific problems, but have never been described in the literature. As a rule, emphasis is placed on the results of the observations and experiments rather than on the exact means by which the data were measured.

Recently, how to measure the length of a fish has been thoroughly discussed by Ricker and Merriman (1945) and Hile (1948). These authors have listed eleven methods of measuring fish lengths. Of these eleven, three refer to total lengths measured from the anterior end of the fish (this point usually being the tip of the jaw) to the extreme points of various parts of the tail fin. The measuring of total length can be readily and accurately effected by a simple board with a "head stop" and a graduated rule. The method of recording on celluloid sheets the total lengths by perforations at the point of measurement, as mentioned by Buchanan-Wollaston (1928) and Thompson (1929) is advantageous when one is interested in securing length frequencies of the populations. The other eight measurements are "standard" lengths, which involve distances between the anterior end of the fish and various anatomical

structures located short of the posterior end of the fish. The determination of any of these eight measurements is greatly assisted by the use of special devices similar to that of Hiatt and Hamre. "Standard" lengths are commonly used for determining the length of herring and sardines, because the tails of those species are often damaged in the commercial fishery.

Williamson (1900) satisfied his own need for a rapid and accurate method of obtaining various body measurements on the mackerel, such as between the tip of the jaw and the end of the operculum, the tip of the jaw and the anterior insertion of the dorsal fin, etc. His device measured these distances in a plane parallel to the axis of the body of the fish, as does that of Hiatt and Hamre. Williamson (1914) used this measuring board also on the herring. As this apparatus was rather primitive and has been succeeded by more durable and efficient modifications, there is no need of describing it in detail here.

Riddell (1914) described an improved version of Williamson's board and his apparatus closely resembles the models used by the herring and sardine investigators in Canada and the United States. In altering Williamson's device, Riddell, among other changes in design, substituted a cross wire for a cross thread and brass moving parts for wooden ones. The measuring boards described by Thompson (1917, 1926) and Rounsefell (1930) are basically similar to the Riddell board.

These boards operated on the same general principle as that of Williamson's, but each improved model was more durable and more easily operated. These devices are adequately described in the above references. During a recent investigation of the Maine herring, a board patterned basically on Rounsefell's design, but with a base of Lucite instead of brass on wood and with the cross wire in intimate contact with the millimeter scale to eliminate the use of a mirror for the reduction of parallactic effect, gave excellent service.

While boards similar to the Riddell model and the subsequent slight modifications have been satisfactory in most instances, there have been several investigators who have felt the need for more radical alterations in its design. Hart (1936) felt that these types of boards could be improved to eliminate the eyestrain which often occurs when one uses the boards for a considerable period of time. It is necessary before reading the scale to align the cross wire, the image of the cross wire in the mirror, and the point on the fish. Hart's device eliminated the need for a mirror, but the apparatus had somewhat more complicated moving parts and is not in common usage, to my knowledge. Sette (1941) noted that digit bias was prevalent among his colleagues who measured sardines with a modification of the board used by Riddell. To eliminate such bias, he incorporated in the measuring mechanism a mechanical selector which relieved the user of the responsibility of selecting, by eye, the nearest millimeter.

There is one method by which the digit bias could be considerably reduced without the use of Sette's mechanical selector. The measurer can consider each distance between the millimeter marks as a single unit, rather than determine whether the measurement which falls nearly half way between the

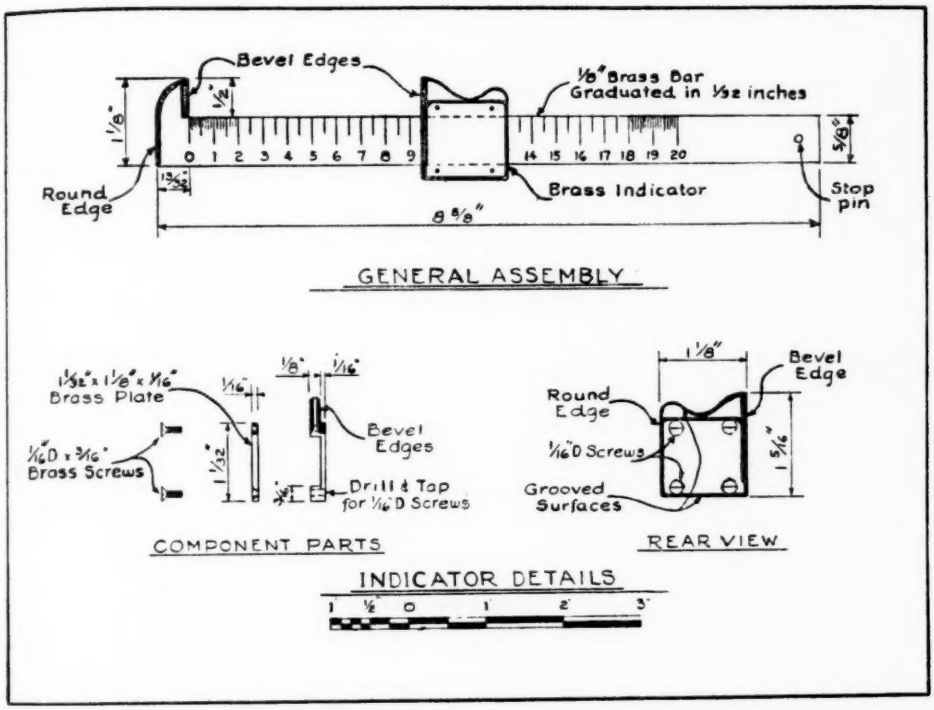

FIG. 1. Lobster measuring caliper.

two millimeter graduations should be credited to the lower or higher millimeter value. For example, when a fish is 52.49 millimeters long, it is rather difficult to decide whether it should be recorded as 52 or 53 millimeters and digit bias may have its influence on decisions of this kind. If one considers any measurement falling between 52 and 53 millimeters as 52 millimeters, then trouble of this nature is not so prevalent, although there is still some difficulty in deciding whether the fish measures less or greater than the millimeter mark. However, at least in this case there is a definite mark to indicate the boundary of the millimeter intervals. Then, for example, the actual value of the recorded number 52 is 52.5 (range 52.00 to 52.99), instead of the usually understood value 52.0 (range 51.50 to 52.49). This fact must be borne in mind in later analyses of the data. Scales which are offset one-half or one and one-half graduations are often used, so that one measures only between the graduations, but still retains the common mean value and range.

During recent years, I have employed a caliper device which was originally planned for measuring the lengths of lobsters, but was later also used for other invertebrates, including mollusks. When measuring lobsters, one determines the straight line distance between the posterior margin of the eyesocket and the posterior end of the carapace. Maximum and minimum size regula-

tions in United States lobster-producing states are based principally on this type of carapace measurement. Size regulations concerned with total lengths as measured from the tip of the rostrum to the end of the tail were generally unsatisfactory because evaders of the law could break off the rostra to decrease the total lengths or increase the lengths by stretching the membranes between the tail segments and between the junction of the tail and carapace.

The first caliper which I devised for use in measuring lobsters was one built from celluloid and graduated in millimeters. This proved to be fairly satisfactory, but had two principal drawbacks. First, it did not withstand hard usage in the field and, second, there was no particular need for measuring and recording the lobster sizes in millimeters when all size regulations were already based on the English system of inches. I was unable to find any suitable commercial caliper for my use, so I designed a model of simple and rugged construction which has proven satisfactory to all who have used it since 1941. Figure 1 illustrates the latest model, built entirely of hard brass. I am fully aware that many such caliper devices have been probably used in the past, but nevertheless, I present this apparatus with the hope that others may also be able to utilize it profitably.

As can be noted from the figure, the graduations mark thirty-seconds of an inch and are grouped in tens. For brevity, 10 on the scale is represented by the numeral 1, and 20 by 2, etc. The graduations by tens of thirty-seconds facilitate rapid reading of the scale because of the elimination of the usual half, quarter, eighth, sixteenth, and thirty-second units so often seen on rulers. It was found desirable to measure lobsters in thirty-seconds of inches, but in other cases it might be accurate enough to measure in larger units as sixteenths or eighths. Whatever unit of the English system is used, it is an advantage to have the units grouped in tens.

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THE REPRODUCTIVE CYCLE OF THE MUSKRAT IN WISCONSIN[1]

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In spite of the large amount of work that has been done on the eastern muskrat, *Ondatra zibethica zibethica* (Linn.), and the volume of literature that has been written about it, very little seems to be known about its basic reproductive cycle. The work of various authors has placed the gestation period at from 19 to 30 days (Errington, 1937; Smith, 1938; Ulbrich, 1930). It seems probable that the period of about 22 to 25 days is near the true gestation period, with the longer periods coming from delayed implantation as they do in the house mouse (*Mus musculus*) (Mirskaia and Crew, 1931) and *Peromyscus* (Svihla, 1932) during lactation. Enders (1939) and Forbes and Enders (1940) came to the tentative conclusion that the ovulatory cycle in the muskrat is about 30 days. This was based on a histological study of ovaries taken during the spring in Maryland.

The present study elaborates on the ovulatory or estrous cycle and on the estrous and anestrous seasons in the muskrat. The animals obtained for laboratory observations came from the vicinity of Madison, Wisconsin. The field observations were made primarily in Dane and Dodge Counties, Wisconsin.

[1] A contribution from the Zoological Laboratory, Univ. of Wisconsin.

THE BREEDING SEASON IN WISCONSIN

Information on the length of the breeding season is based primarily on the examination of 109 litters in the nest. The breeding season, as considered in this paper, will be that period during which the muskrats are sexually active rather than that period during which the litters are born. The estimated birth dates of the first litters found, based on their size and stage of development, were April 28, May 5, and April 30 for 1946, 1947, and 1948 respectively. Assuming a 25-day gestation period, this would place the beginning of the breeding season during the first 10 days of April. Litters were not found in quantity until after the 15th of May, and only a few litters were found that were born after the first week in July. Unfortunately the litter data do not lend themselves to showing a frequency distribution, since most of the work of locating litters was expended at the

beginning and towards the end of the season.

Of 1,755 immature muskrat pelts examined in the first 10 days of November of 1946, 169 were classed as kits. These animals were estimated to be between 70 and 95 days of age and thus most of them were born in August. One animal taken November 3 was estimated to be between 45 and 50 days of age. This would place the time of birth at about the 15th of September. The examination of 612 adult females taken in November of 1946 and 1947 (the bulk during the first 4 days of the month) failed to reveal a single pregnant or lactating animal. I have one trapper's report, which I consider to be reliable, of finding small embryos in a female taken during the last part of February. Hatfield (1939) found that two of 207 females taken between March 20 and 24 in Minnesota contained embryos. Thus most of the breeding takes place between early April and late June with occasional breeding taking place as early as the middle of February and as late as the middle of August in southern and central Wisconsin. This information agrees with the findings of Errington (1937) for northwest Iowa, but the spread of the major peak of breeding seems to be a little shorter than that listed by him.

TABLE 1.—ESTROUS CYCLES BASED ON VAGINAL SMEARS

Animal	Length of Cycles in Days
46—2 adult	26, 24
47—1 immature	30, 28
47—2 adult	28, 26
48—1 immature	30, 26
48—2 adult	31
48—4 immature	34
48—5 ?	33 average of 28.7 days

THE ESTROUS CYCLE

Long and Evans (1922) have shown that the stage of the estrous cycle in the white rat is determinable by the examination of a vaginal smear. The same is true of the hedgehog (Deansely, 1934), the bank vole (Brambell and Rowlands, 1936), the guinea pig (Young, *et al.* 1933) and the cotton rat (Meyer and Meyer, 1944).

Female muskrats were live-trapped during the latter part of March, which is before the breeding season, and placed in individual wire cages in an outdoor courtyard where light and temperature conditions were normal. Ten females were captured and handled in this fashion and data from one or more complete cycles were obtained from seven of these.

By taking daily vaginal smears with a pipette through 11 complete cycles it was found that the estrous cycle averaged 28.7 days, with a variation of from 24 to 34 days (see Table 1). The cell types found in a typical cycle are shown in Fig. 1. It can be seen that there is some variation in cell types from day to day but that this fluctuation never becomes great enough to mask the true picture. The percentages used to show cell-type composition were obtained by taking counts from three microscope fields and recording the average obtained. During the diestrous period the smear is made up primarily of leucocytes with some nucleated epithelial cells. This period lasts about 27 days on the average. The estrous or heat period lasts but one day and the smear is composed primarily of sheets of cornified epithelial cells. Since the smears were taken once a day, it was not possible to obtain a detailed picture

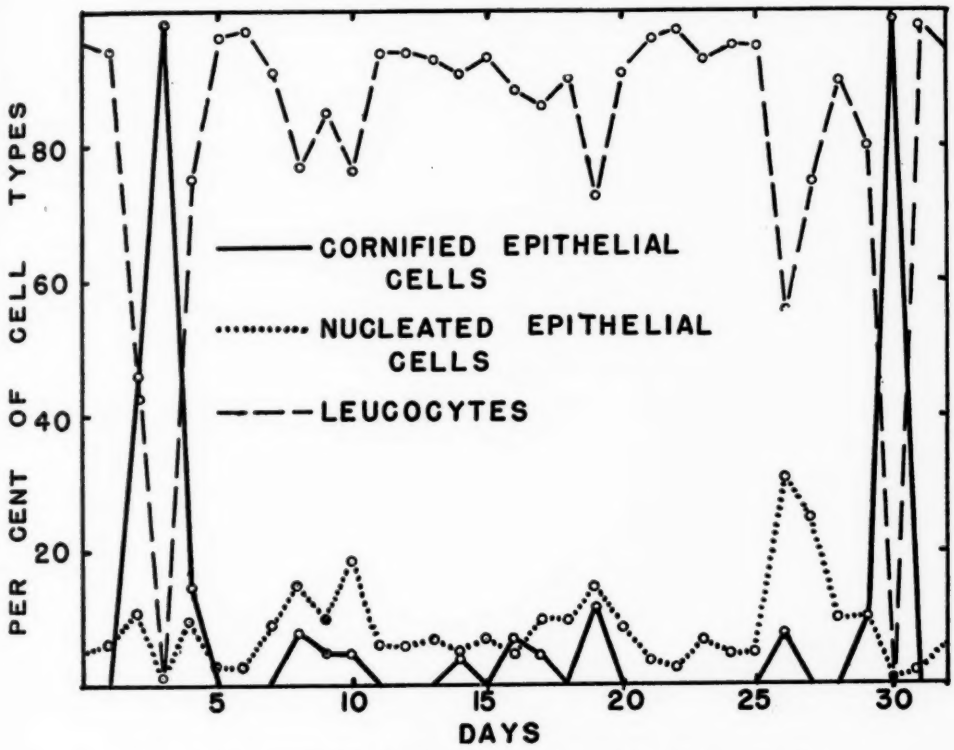

FIG. 1. Cell types found at the various stages of the estrous cycle based on a typical cycle.

of the changes that take place just before and immediately after estrous. During estrous there is a certain amount of swelling about the lips of the vagina. Two animals killed towards the end of the estrous period had ovulated very recently. Since these animals had been isolated in pens, ovulation must have been spontaneous. None of the 22 females having diestrous smears showed recent ovulation during the breeding season.

The data given by Errington (1937) show rather conclusively that there is a postpartum estrous in the muskrat, as there is in the house mouse (Mirskaia and Crew, 1931), the bank vole (Brambell and Rowlands, 1936), and the cotton rat (Meyer and Meyer, 1944). Field observations indicate that two or three litters are the usual rule. Observations of seven rather isolated females in the field indicated that each raised two litters and that two of these had a third litter. It is possible that some litters were missed so that the number having a third litter might be slightly increased. Errington (1937) has shown that most of the muskrats in northwest Iowa raise two or three litters and that in rare cases may even have a fourth.

THE VAGINAL ORIFICE

The vagina is closed in the muskrat at birth and apparently does not normally open before the beginning of the

breeding season the following spring. The 19 immature animals that had open vaginas during November (see Table 2) were probably animals that had been roughly handled and the membrane broken in this way before they were brought to the skinning station. This opening of the vagina in southern Wisconsin muskrats comes for the most part in March (see Table 2). This would make the opening date for the vagina about a month before the beginning of breeding. Long and Evans (1922) in their work on the white rat found that about half of the rat vaginas become perforate with the first ovulation, though many others were found to open a few days before. This is about the same as the picture given by Parks (1925) for the house mouse.

While the first ovulation takes place at about the time of the opening of the vagina in the house mouse, it was found by Mirskaia and Crew (1930) that copulation often does not take place at that time and if it does the incidence

TABLE 2.—FREQUENCY DISTRIBUTION OF OPEN AND CLOSED MUSKRAT VAGINAS BY TWO-WEEK PERIODS

		Adult		Immature	
		Open	Closed	Open	Closed
March	1–15	—	—		
March	16–31	18	1		
April	1–15	1	0		
April	16–31	1	0		
May	1–15	2	0	0	2
May	16–31	2	0	0	3
June	1–15	15	0	0	41
June	16–30	9	0	0	16
July	1–15	4	0	0	5
July	16–31	2	0	0	2
August	1–15	2	0	0	1
August	16–31	1	0	—	—
September	1–15	1	0	0	7
September	16–31	1	0	—	—
October	1–15	—	—	0	3
October	16–31	4	0	—	—
November	1–15	141	49	19	1,168
November	16–30	33	12	0	0
December	1–15	17	7	0	9
December	16–31	3	1	0	7
January	1–15	—	—	—	—
January	16–31	1	0	—	—
February	1–15	0	2	—	—
February	16–28	1	2	0	7
		259	74	19	1,271

of pregnancy is low. Deansely (1934) found that the hedgehog in England ovulates spontaneously and goes through one or more short ovulatory cycles before mating. Enders (1939) and Forbes and Enders (1940) found embryos in none of the 119 females that they examined between November 30 and March 15 in Maryland. Since most of the 22 ovaries examined by them during the second week in March had true corpora lutea, it is probable that pregnancy does not take place with the first ovulatory cycle in the estrous season.

After the breeding season is over, about one-third of the adult females have the vagina reclosed (see Table 2). The closure of the vagina seems to come during the latter part of October in this area. Brambell and Rowlands (1936) found a well marked winter anestrous in the bank vole in England. At this time the vaginal orifice was closed. This closing is usually incomplete in the muskrat, as an opening of about one-eight of an inch in diameter perforates the membrane. In the occasional animal that does show a complete closure, the membrane is extremely thin and breaks readily. Baumgartner and Bellrose (1943) found no adult females with a completely closed vagina in examining over 1,000 adult females. My observations show that 4 out of 333 adult females examined had completely closed vaginas. In the immature females the vaginal membrane is relatively thick, and considerable pressure is required to break it.

SUMMARY

The breeding season of the muskrat in southern and central Wisconsin is from about the first week in April to the middle of June, with occasional animals sexually active as early as the middle of February and as late as the middle of August.

The estrous cycle, as based on vaginal smears taken on 7 animals during 11 complete cycles, averaged 28.7 days.

The vaginal orifice opens in March, and about one-third of the adults have at least a partial reclosure which takes place about the last of October.

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OBSERVATIONS ON HISTOPATHOLOGICAL CHANGES ASSOCIATED WITH STARVATION IN WISCONSIN DEER

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Heavy winter losses in deer, apparently resulting directly from an inadequate food supply, have long been known in the United States. The general situation has been well reviewed by Leopold (1943) and by Leopold, Sowls, and Spencer (1947). There is a considerable volume of literature available concerning deer starvation from the management standpoint. The ill-advised attempts at the total destruction or, at best, the severe reduction of natural predators on deer have resulted in the removal of this important population control. In addition to this, in most regions there is so much public antagonism to artificial control of deer populations that it is rarely effected, even though it be recognized by qualified men that remedial measures are necessary.

The observations recorded in this paper were made during a study of helminth parasitism in Wisconsin deer. This permitted a brief exploration of verminous bronchial pneumonia which, according to some writers, is often an important accompanying condition associated with malnutrition. With this in mind, I autopsied about 20 Wisconsin deer dead from starvation without finding any evidence of pneumonia, even though heavy lung-worm infections (*Protostrongylus*) were present. The post-mortem alterations in these carcasses did not allow completely satisfactory results. Through the generous cooperation of the Wisconsin Conserva-

[1] Now with the U. S. Public Health Service, Box 960, Anchorage, Alaska.

tion Department, it was later made possible for me to collect deer from an area where starvation was much in evidence.

Five starving deer were collected by shooting on March 9 and 10, 1948, at the time of the year when the deer were suffering most heavily from food shortage. An effort was made to select animals obviously suffering from the effects of inadequate diet. We were successful in this, although it is well known that deer usually show little visible effect of starvation until they are near death. In this study, I was aided in the collection of these deer by Messrs. Bruce Stollberg and Harry Stroebe, of the Game Division of the Wisconsin Conservation Department, and by Mr. Werner Radke, of the Department's Enforcement Division. This opportunity is taken to express my appreciation of their aid.

I realize that 5 animals hardly represent an adequate sample. It is difficult, however, to justify the destruction of a very large number of deer for research purposes only, in view of the usual public reaction to such activities. Two normal deer, for comparative purposes, were obtained later during the early fall.

The 5 starved deer studied were collected in the central part of Wisconsin, in Jackson County, while the normal animals came from the northern part of the State. At the time the deer were obtained there were about 6 inches of snow, and subzero temperatures. Although the area from which the deer were taken is far enough south so that the animals do not yard, there was much evidence of overbrowsing, and an intensive program of artificial feeding was being carried out. We found a considerable number of fawns dead in the feeding areas, where alfalfa hay and concentrate were available. Stollberg (1949) has given additional information on this situation.

The deer were autopsied immediately after being shot, and the desired tissues were fixed at once in 10 per cent formalin and in formalin-acetic acid-alcohol solution. Blood smears were unfortunately ruined by the subzero temperatures, since they froze immediately when made. The tissues fixed in formalin-acetic acid-alcohol were imbedded in paraffin, sectioned, and stained with Weigert's haematoxylin with a modification of Crossman's modification of Mallory's triple stain. Tissues fixed in 10 per cent formalin were frozen-sectioned and stained with Sudan IV for fat. The latter method was applied routinely to bone marrow, kidney, liver, and heart tissue. Bensley's mitochondria stain was applied to the bone marrow. The prussic acid test was applied to splenic tissue as a test for iron pigments and, in some cases, other special techniques were used.

RESULTS

The histological findings for the five starved deer were in general the same; however, each animal is considered separately in order to allow a more complete report.

Deer I: A female fawn weighing 51 pounds; very thin, but not noticeably weak. Some indication of the age of this animal can be gained from the fact that one permanent molar and one permanent incisor were present. Gross findings of a pathological nature were few. However, the heart was noted to be very

flabby and yellowish in color, and the bone marrow was gelatinous. The animal was killed in an area where some downed pines furnished temporary food. However, dead fawns of a similar size (from 50 to 55 pounds) were picked up in the immediate area.

Microscopical findings: A marked decrease in the fat content of the bone marrow of both the shaft and head of the long bones was obvious. Few hemopoietic cells were seen (Plate 6A). The spleen showed thickening of arterial walls (Plate 6B), and a decrease in size and number of follicles. Considerable hemosiderin was seen throughout the spleen; this was identified by Turnbull's method. An unidentified pigment which remained unstained by the above reaction was also present in considerable quantities. Fatty degeneration had taken place in the heart. The liver showed abundant hemosiderin in the Kupffer cells, as demonstrated by the Turnbull method. A finely-granular pigment was observed in the cytoplasm of the liver cells in the areas surrounding the central veins. This pigment stained red by Turnbull's reaction. According to Lillie (1947) this pigment would be hemofuchsin. The kidneys showed chronic passive congestion and a thickening of arterial walls. A granular material, which stained red with acid fuchsin, was abundant in Bowman's space and within the proximal convoluted tubules. A proliferation of the cells of Bowman's capsule was noted. The lungs were normal except for numerous granulomatous lesions resulting from lung-worm infections (Plate 6C). In this animal, an average of 10 granulomata were seen per low-power field. Eosinophiles were numerous in the subepithelial connective tissue of the small intestine.

Deer II: An adult female, at least 3 years old; very thin, weighing only 90 pounds. Except for the gelatinous bone marrow, there were no striking gross lesions. The heart was not obviously affected.

Microscopical findings: There was a marked decrease in the amount of fat in the marrow of the long bones. Hemopoietic cells were rare. A thickening of the arterial walls was seen in the spleen, along with a decrease in the size and number of follicles. Hemosiderin was abundant in the spleen, as was the unidentified pigment observed in the spleen of deer I. Some fatty degeneration of the heart was noted. Hemosiderin was abundant in the Kupffer cells of the liver. The kidneys showed chronic passive congestion and a thickening of the arterial walls. A granular material was abundant in Bowman's space and in the proximal convoluted tubules (Plate 6D). A proliferation of the cells of Bowman's capsule was also noted. The lungs were normal except for numerous lung-worm granulomata. Eosinophiles were numerous in the subepithelial connective tissue of the small intestine. The mesenteric lymph nodes showed a thickening of the arterial walls, moderate fibrosis, and a marked decrease in the size and number of follicles.

Deer III: A small adult female, weighing 104 pounds, in relatively good condition. Some subcutaneous fat was present, along with considerable fat on the mesentery. Fat was also rather abundant in the bone marrow, which appeared nearly normal in contrast to the gelatinous marrow seen in the other animals. A single fawn was found in the uterus of this animal. A cysticercus of

Taenia sp. was observed on the surface of the liver.

Microscopical findings: The bone marrow was nearly normal in fat content, although there was some decrease in amount. Hemosiderin was abundant in the spleen, and there was a decrease in the number and size of the splenic follicles. The endothelial lining of the arterioles, along with the subepithelial connective tissue, extended into the lumen; in many of the arterioles the lumina were nearly occluded. The arterial walls were thickened. The heart showed chronic passive congestion. Hemosiderin was abundant in the liver, and there was a marked fibrosis of interlobular tissue. The epithelium of the bile ducts showed considerable proliferation. The kidneys showed a tendency toward a high cellularity of the glomerular tufts, with a small amount of granular material within the Bowman's space and in the tubules. The lungs were normal except for a moderate number of lung-worm granulomata (2 or 3 per low-power field). The intestine showed a moderate infiltration by eosinophiles and lymphocytes.

Deer IV: A 51-pound male animal, in poor condition. Two permanent molars, the second just coming through, and two permanent incisors were present. This animal was found lying among the alfalfa piles in a feeding area. It ran rather well when disturbed, but was easily overtaken and shot. The heart of this animal appeared good on gross examination, with little evidence of fatty degeneration. The bone marrow was gelatinous.

Microscopical findings: The bone marrow showed practically no fat. The spleen showed an abundance of hemosiderin, and proliferation of arterial walls with the attendant projection of the lining into the lumina. The follicles had decreased in size and number. No changes were seen in the heart. The nuclei of the hepatic cells showed vacuolation. Interlobular fibrosis was noted, accompanied by some atrophy. Hemosiderin was abundant in the Kupffer cells. A marked fibrosis of the arterial walls was seen in the kidneys. A small amount of granular material was seen in the proximal convoluted tubules and in the glomerular space. The lungs were normal except for lung-worm granulomata (about 1 per low-power field). There was a moderate infiltration of eosinophiles in the small intestine.

Deer V: An emaciated female animal, weighing 54 pounds. Three permanent molars were present, with the third one just coming through. The animal was obviously weak. The heart was flabby and yellowish in color, and the bone marrow was gelatinous.

Microscopical findings: There was little fat in the bone marrow, and hemopoietic cells were not observed. The spleen showed thickening of the arterial vessel walls, with the mucosa projecting into the lumina. The heart was markedly congested and showed fatty degeneration. Although the animal was young, there was considerable pigment around the nuclei of the cardiac muscle cells. There was some hemosiderin in the Kupffer cells of the liver. There was a thickening of the arteriole walls of the kidney. A red-staining granular material was apparent in Bowman's capsule, and in the proximal convoluted tubules. The lungs were normal. Eosinophiles were present, but not numerous, in the small intestine.

DISCUSSION

Numerous retrogressive changes appeared in the deer suffering from starvation. These findings indicate that even the animals which seem to be in good condition (as deer III) may have suffered considerable damage. The importance of such damage to the animal which survives the periods of malnutrition is not understood; it may be, however, that such damage might contribute to a gradual deterioration of the herd in general.

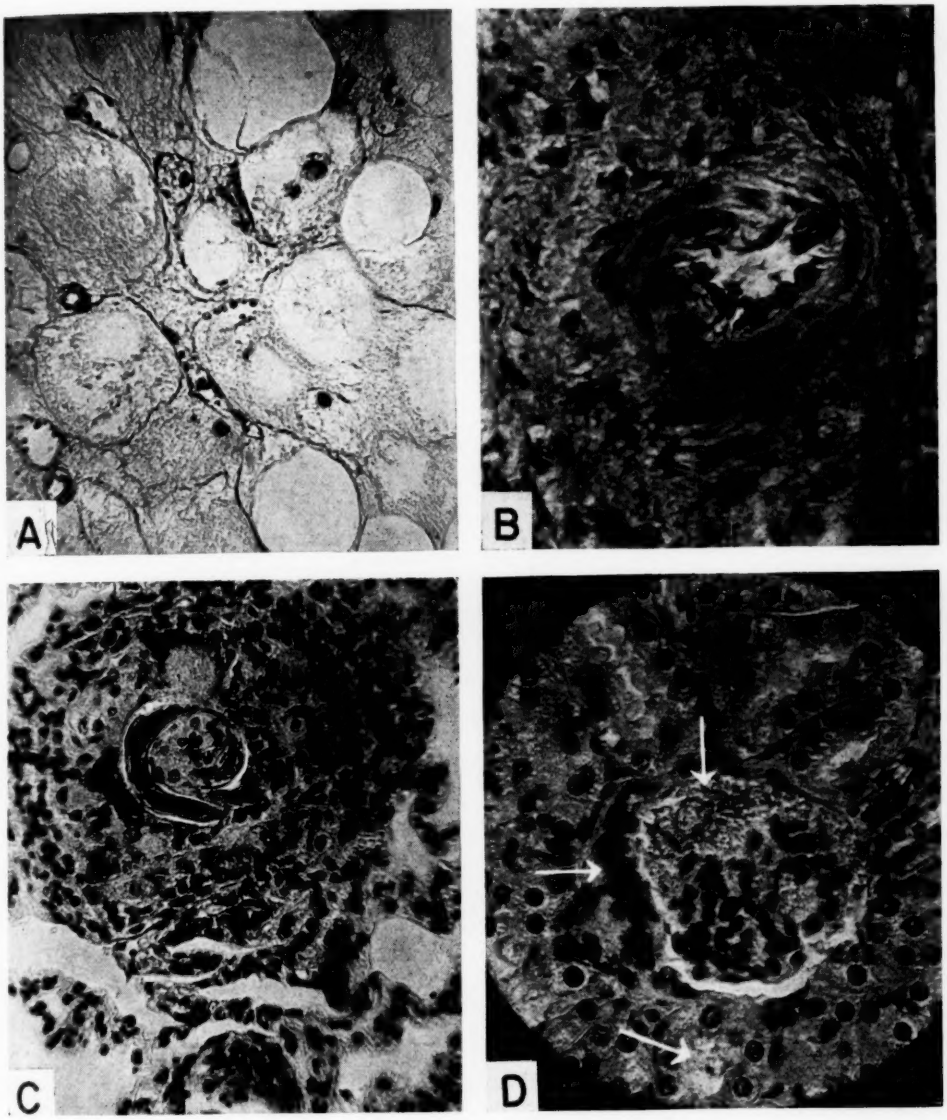
Little information is available on the normal histology of the white-tailed deer. We have made comparisons with the tissues of two normal deer obtained during the early autumn of 1948. These animals, an adult doe and a fawn, were collected before any browse shortage developed. With the exception of lungworm granulomata, these animals showed none of the changes recorded above.

Although the presence of considerable hemosiderin in the spleen of adult deer is a normal condition, it probably represents evidence of excessive blood destruction in fawns. It is generally accepted that pigment around the nuclei of the cardiac muscle cells in some mammals (*e.g.*, man) occurs only in old age. This condition in a young animal (deer V) probably should be considered pathological. The situation in the spleen in regard to the apparent thickening of the arterial walls is not clear. It is possible that with the diminished splenic activity the organ contracts, allowing the arterioles to contract and give the appearance that their walls are much thickened. I am of the opinion, however, that the muscular coat of these arteries and arterioles was hypertrophied. Mitochondria of the granular type were abundant in the cytoplasm of the fat-cells in the bone marrow of the starved deer. These fat-cells contained no fat droplets, as mentioned above. Such mitochondria were also observed in the bone marrow of the normal deer in cells which contained no fat. Although a few mitotic figures may be seen in the epithelium of the intestine of normal animals, they were particularly numerous in two of the starved deer.

Certain conditions observed in the starved deer appear to be particularly evident. They were: abundant hemosiderin in the spleen of the fawns; marked decrease in the amount of fat in the bone marrow; rarity of hemopoietic cells in the bone marrow, and reduction in number and size of follicles in the spleen; a deposition of acidophilic granular material in Bowman's space and in the proximal convoluted tubules of the kidneys, along with cellular hypertrophy of Bowman's capsule; fatty degeneration of the heart.

The only commonly observed helminth, in addition to lung-worms, was *Ostertagia odocoilei* Dikmans, 1931. Light infections of this nematode were seen in most of the deer examined. A cysticercus of *Taenia* sp. was found on the surface of the liver of one animal. Some of the animals were found to be heavily infested with a louse, *Cervicola virginianus* (Peters) 1930; in some cases these were found in large numbers on starved deer which had been dead for some time.

As mentioned earlier in this paper, I have seen no evidence of pneumonia, verminous or otherwise, in any of the deer I examined. Nearly all the deer



EXPLANATION OF PLATE 6.

A. Bone marrow, stained with haematoxylin and Crossman's triple stain, showing lack of hemopoietic cells in the epiphyseal region. High power.
B. Apparent thickening of wall of arteriole in the spleen. High power.
C. Typical lung-worm granuloma in the lung. High power.
D. Glomerulus of kidney showing proliferation of Bowman's capsule and granular material in Bowman's space and in proximal convoluted tubule. High power.

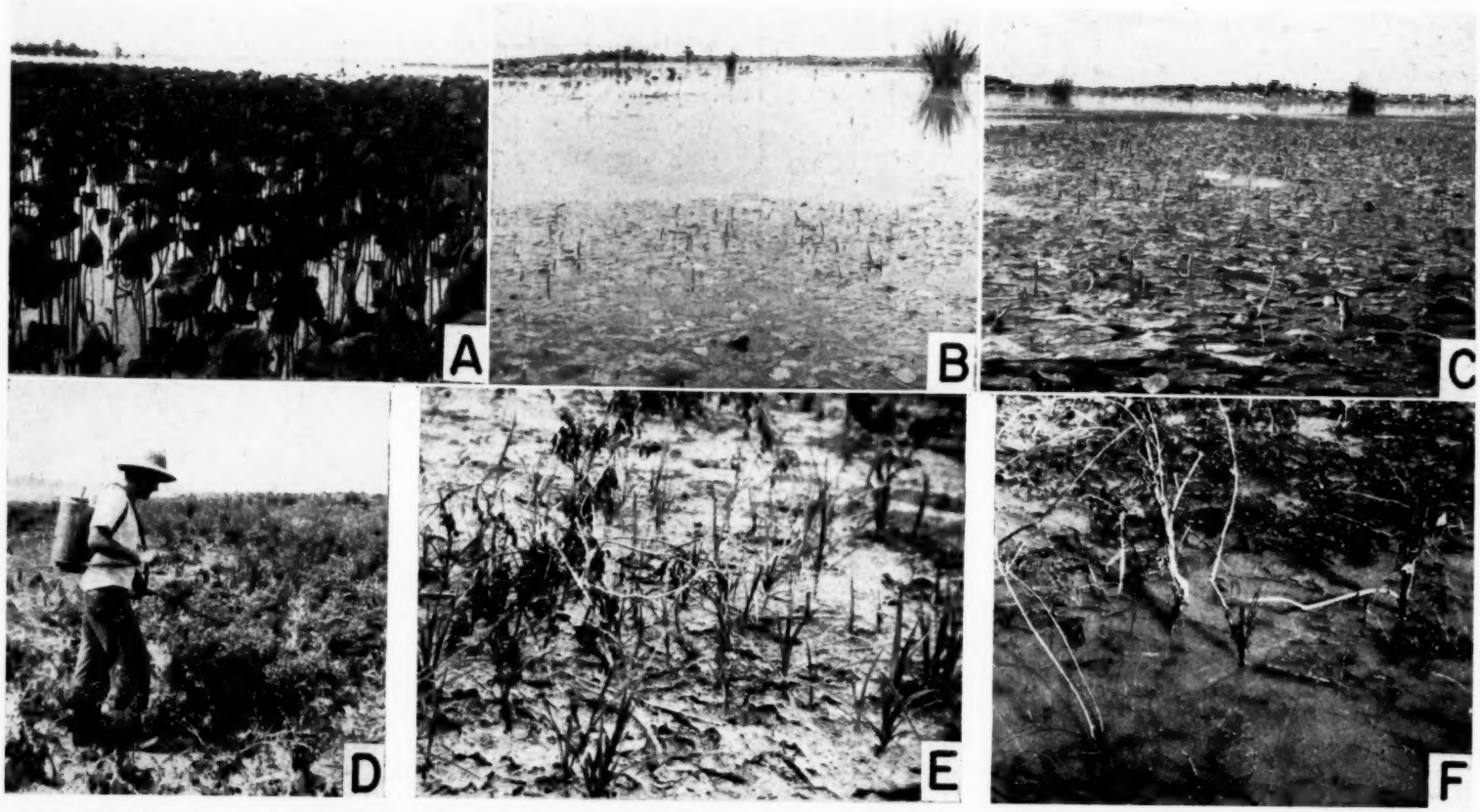


PLATE 7. *Above:* Successive stages in effects of lotus treatment at Reelfoot Lake. A.—Twenty days after treatment; B.—Twelve months after treatment; note longleef pondweed coming in; C.—Two years later, longleaf pondweed has replaced lotus. *Below:* Successive results following the spraying of trumpetvine with 2,4-D (.6%): D.—Application; E.—Effects: trumpetvine dead and chufa coming in; F.—Use: chufa tubers puddled-out by ducks.

examined, including those found dead, were infected with *Protostrongylus* sp. The requisite conditions as outlined by O'Roke (1948) existed ("abnormally high population of deer, the adult deer generally infested, environmental and intermediate host conditions such that fawns have early opportunities to become heavily infested, . . . a shortage of food and resultant malnutrition, weather conditions such as an exceptionally severe or an exceptionally late winter storm . . . ")—supposedly predisposing the animals to verminous pneumonia. It should be pointed out also that the majority of the animals dead from starvation were fawns—*i.e.*, animals born the previous spring. No evidence of pneumonia could be demonstrated in any of the animals dead from starvation. Neither did I observe the "interstitial pneumonia" reported by Goble (1941). It is possible that the animals studied by him had been affected by conditions brought about by their confinement in the George Reserve. Possibly they became more heavily infected with lung-worms than do the animals living under natural conditions in Wisconsin.

In conclusion, I am of the opinion that winter deer losses in Wisconsin are caused directly by starvation uncomplicated by verminous pneumonia. Post-mortem hemostasis in the lungs of deer dead from starvation may be frequently interpreted as evidence of pneumonia by non-technical personnel.

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STUDIES ON THE USE OF HERBICIDES FOR IMPROVING WATERFOWL HABITAT IN WESTERN KENTUCKY AND TENNESSEE

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A primary means of maintaining local and continental populations of waterfowl is through improvement of the limited marsh and aquatic habitat that still remains. In many localities, this can be accomplished best by controlling vegetation that does not clearly pay its way in usefulness to wildlife. When undesirable plants are curbed or eliminated, the way is opened for establishment of more useful species—either with or without the aid of man.

Investigations on chemical control of pest plants in waterfowl habitat were conducted on Reelfoot Lake, Kentucky Woodlands National Wildlife Refuge and Kentucky Reservoir (TVA) from the period 1945 to 1949 inclusive.

In this region, the problem of improving waterfowl habitat has special complexities. Here ducks and geese utilize not only relatively stable marsh and aquatic areas but also agricultural fields and other tracts which are alternately drained and inundated by manipulation of levels in large man-made reservoirs. Consequently, the kinds of vegetation requiring control include numerous upland plants which persist in seasonally flooded units, as well as objectionable swamp, marsh, and aquatic species.

This report presents details on experimental control of some of the more important pest plants and outlines conclusions relating to control procedures with chemicals.

Acknowledgments are due to several companies which supplied chemicals for use in these experiments, notably: E. I. Du Pont de Nemours, Dow Chemical, American Chemical Paint, Plant Products, Sherwin-Williams, B. F. Goodrich, and the Carbide and Carbon Chemicals Corporation. Also, valuable cooperation and advice was received from the following individuals: A. C. Martin and F. M. Uhler, of the Patuxent Research Refuge; W. A. Scheicher and John Morse of the Kentucky Division of Game and Fish; G. H. Baker, W. R. Sylvester, P. Lane, and R. Ramey, of the Kentucky Woodlands National Wildlife Refuge; E. V. Pierce, W. W. Fickle, K. E. Meyers, and H. C. Phillips of the Reelfoot National Wildlife Refuge; and C. L. Baker and R. J. Schoffman of the Reelfoot Lake Biological Station.

Materials and Methods

Two herbicides used extensively in these studies were 2,4-D (including 2,4-dichlorophenoxyacetic acid and its salts and esters) and Ammate (ammonium sulfamate). Limited tests were made with other chemicals including 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), Atlacide (chloric acid and equivalent in calcium), derivatives of phenyl carbamate, chlorophenyl allyl carbonate, and sodium arsenite.

Cylinder-pressure and knapsack sprayers were used in applying herbicides to foliage. In treating tree trunks

the injection method described by Pessin (1942) was employed, and stumps were painted with chemicals.

When possible, water- instead of oil-carried herbicides were used in order to curtail expense of treatment. This usually necessitated the use of a wetting agent though many commercial herbicides now on the market, especially 2,4-D, have a wetting agent or spreader added to them. Commercial soaps, household cleaning detergents (Tide, Vel, etc.), sulphonated alcohol, and DuPont Wetting Agent, In-181-P, were used commonly in these studies. Tergitol Wetting Agent 4, one of a group of sodium secondary-alcohol sulphates, was found to be especially effective and was also used extensively.

Herbicide applications were made in graded concentrations and were replicated for different stages of plant growth and in varied types of environment. In all, more than 350 plots of vegetation were treated. Observations of results were made periodically following application and, in many instances during the course of succeeding growing seasons. Effects on plant succession were noted. Notes were also kept on the effects upon useful species found in the plots since it is desirable to be able to anticipate the consequences of incidental spraying on them. If treatments were successful on preliminary tests, they were repeated on plots ranging from 1/40 to 1/10 of an acre. Finally, if results seemed to justify it, demonstrations were made on tracts of an acre or more.

THE PRINCIPAL PEST PLANTS AND THEIR CONTROL

Tests were centered on plants that are especially objectionable in the Western Kentucky and Tennessee region because they crowd-out vegetation valuable to waterfowl. Among the worst of these offenders are a number of woody plants that survive in seasonally or permanently flooded places. In addition, two coarse herbaceous weeds, lotus (*Nelumbo pentapetala*) and giant cutgrass (*Zizaniopsis miliacea*), of marsh and aquatic situations, received special attention. The weed-status of these problem plants and their responses to herbicides are outlined below.

Woody Plants

Among the woody pest plants in this general vicinity, the worst by far is buttonbush (*Cephalanthus occidentalis*). This swamp shrub constitutes about 75% of the regional problem. Preliminary tests showed that for buttonbush and other woody growths, the most vulnerable period for treatment is in the last two weeks of August—in this area. A large-scale demonstration on the control of this plant was conducted at Honker Lake, Kentucky Woodlands National Wildlife Refuge on August 20–30, 1946. Ammate ($\frac{3}{4}$ lb. to a gallon of water) was sprayed thoroughly over the foliage with very satisfactory results. The spraying was localized so as to avoid, as far as possible, damage to associated smartweeds (*Polygonum*) and the subsequent increased growth of these desirable plants helped to suppress re-sprouting of the treated buttonbush. 2,4-D did not control this shrub.

Trumpetvine (*Tecoma radicans*) inclines to dominate some of the seasonally-inundated islands that are used extensively by waterfowl. Commonly

this vine competes aggressively with chufa (*Cyperus esculentus*). On islands, in the Kentucky Reservoir, trumpetvine was sprayed with 0.6% 2,4-D on August 15–September 20, 1947 and 1948. Caution was exercised to keep the 2,4-D concentration low so as not to damage chufa. The treatment was successful (Plate 7). Control of trumpetvine aided in the reduction of another pest competitor of chufa, cocklebur (*Xanthium* sp.). Elimination of brushy anchorage, provided formerly by trumpetvine, prevented the settling and accumulation of drift-borne cocklebur.

Willows, in many localities of this region, constitute a marginal or swamp growth that limits seriously the production of good duckfoods such as smartweeds and pondweeds (*Potamogeton*). These pest species responded best to treatments with 2,4-D during periods of active growth but were also controllable by Ammate, later in the season. Sodium arsenite injected into the trunks was not very effective but a 40% butyl or isopropyl 2,4-D injection proved successful. Treating freshly-cut surfaces of willow stumps with 30% 2,4-D prevented sprouting and this method was also useful on stumps of black locust (*Robinia pseudoacacia*), honey locust (*Gleditsia triacanthos*), and sycamore (*Platanus occidentalis*).

Among the numerous other woody plants that persist in wet or seasonally flooded places, green ash (*Fraxinus lanceolata*) and some of the more water-tolerant oaks are prominent as pest species. On these, as on most woody plants, foliage spraying at the proper time, with either Ammate or 2,4-D, is effective.

Lotus

This large, padleaf aquatic is a major problem-plant in Reelfoot Lake and in many other localities. It thrives in comparatively quiet waters at depths of 1 to 7 feet and competes successfully with plants more useful to waterfowl. The growth of lotus is so rapid—it extends its zone as much as 200 feet in a season—that control operations need to be 95% to 100% effective to be satisfactory. Otherwise, treated stands of the plant are likely to resume their previous dominance in a short time.

Demonstrations of lotus control were conducted at Reelfoot Lake, using both Ammate (¾ lb. to a gallon of water) and 2,4-D (0.6%). Sprayings were made during the first half of August in the years from 1945 to 1949. At this season the lotus plants have attained full vegetative growth and are in a stage of flowering and fruiting. The treatments were regarded as completely successful and the elimination of competition enabled longleaf pondweed (*Potamogeton nodosus*) to spread into places previously occupied by lotus (Plate 7). Subsequently, the refuge personnel made successful, large-scale treatments elsewhere on the lake, using power-spray equipment and a fog nozzle.

Giant Cutgrass

This tall grass is the dominant plant in much of the marsh zone of Reelfoot Lake. Where it is present in dense, continuous stands it is unquestionably a weed since, under those conditions, it has very little waterfowl value to justify the space occupied. If, however, stands of giant cutgrass are sparse or interrupted, ducks make considerable use of its seeds—partly because the

plant seems to seed much more freely under such conditions, and partly because openings in the stands permit ducks to enter and feed. Breaking up extensive marsh growths of this species has proved beneficial. This was accomplished by sprayings with Ammate (1 lb. to a gallon of water) during the time when the plant was most vulnerable to treatment—the second week of August to the first week in September. This is the period when maximum stolon growth occurs. Also, best results were obtained when the plants were standing in about six inches of water or more. It was found essential that in preparing the spray, sufficient detergent be added to enable satisfactory wetting of leaf surfaces.

SUMMARY OF RESULTS WITH AMMATE AND 2,4-D

The approximate extent of control (good, partial, none) obtained by treat-

TABLE 1.—LIST OF PLANTS TREATED WITH AMMATE AND 2,4-D AND DEGREE OF CONTROL OBTAINED
G = Good, P = Partial, N = None

	AMMATE TREATMENT (15%); ¾ lb. to Gal. Water			2,4-D TREATMENT .6% Water-Carried		
	Stage of Plant Growth	Flooded or Wet Marsh	Moist Soils	Stage of Plant Growth	Flooded or Wet Marsh	Moist Soils
Herbaceous Pest Plants						
Common cattail, *Typha latifolia*	Flw. & fruit	P	P	Flw. & fruit	N	N
Giant cutgrass, *Zizaniopsis miliacea*	Max. stolon	P	P	Max. stolon	N	N
Lizardtail, *Saururus cernuus*	Fruiting	G	G	Fruiting	G	G
Dock, *Rumex* sp.	Flw. & fruit	G	G	Flw. & fruit	P	P
Spatterdock, *Nuphar advena*	Max. foliage	P		Max. foliage	P	
Lotus, *Nelumbo pentapetala*	Flowering	G		Flowering	G	
Rosemallow, *Hibiscus militaris*	Flw. & fruit	P	P	Flowering	G	G
Ludwigia, *Ludwigia palustris*	Flw. & fruit	G	G	Flw. & fruit	G	G
Horsenettle, *Solanum carolinense*	Fruiting		G	Flw. & fruit		G
Buttonweed, *Diodia virginiana*	Flw. & fruit	G	G	Flw. & fruit	G	G
Cocklebur, *Xanthium* sp.	Act. growth		G	Act. growth		G
Beggarticks, *Bidens* sp.	Act. growth		G	Act. growth		G
Useful Plants						
Longleaf pondweed, *Potamogeton nodosus*	Fruiting	N		Flw. & fruit	N	
Rice cutgrass, *Leersia oryzoides*	Flw. & fruit	P	P	Flw. & fruit	N	N
Wild millet, *Echinochloa crusgalli*	Flw. & fruit		P	Flw. & fruit		N
Chufa, *Cyperus esculentus*	Act. growth		P	Act. growth		N
Squarestem spikerush, *Eleocharis quadrangulata*	Furiting	G	G	Fruiting	G	G
Duckweeds, *Lemna & Spirodela*	Act. growth	P		Act. growth	N	
Largeseed smartweed, *Polygonum pennsylvanicum*	Flowering		G	Flowering		G
Swamp smartweed, *Polygonum hydropiperoides*	Flw. & fruit	G	G	Flw. & fruit	P	P
Woody Pest Plants						
Some briers, *Smilax* sp.	Maximum foliage in late summer	G	G	Maximum foliage in late summer	G	G
Some willows, *Salix* sp.		G	G		G	G
Cottonwood, *Populus deltoides*		G	G		G	G
Alder, *Alnus rugosa*		G	G		G	G
Some oaks, *Quercus* sp.		G	G		G	G
Elm, *Ulmus* sp.			G			G
Sweetgum, *Liquidambar styraciflua*		G	G		G	G
Sycamore, *Platanus occidentalis*		G	G		G	G
Blackberry, *Rubus* sp.			G			G
Honey locust, *Gleditsia triancanthos*		G	G		G	G
Black locust, *Robinia pseudoacacia*			G			G
False indigo, *Amorpha fruticosa*		G	G		G	G
Silver maple, *Acer saccharinum*			G			G
Red Maple, *Acer rubrum*		G	G		G	G
Boxelder, *Acer negundo*			G			G
Stiff dogwood, *Cornus stricta*		G	G		G	G
Persimmon, *Diospyros virginiana*		G	G		G	G
Green ash, *Fraxinus lanceolata*		G	G		G	G
Trumpetvine, *Tecoma radicans*		G	G		G	G
Buttonbush, *Cephalanthus occidentalis*		G	P		N	N

ing various woody and herbaceous plants with Ammate and 2,4-D is summarized in the table above. In each instance, the information is a composite of results—some of them from different years—rather than the product of a single test at a particular date. All of the results are based on treatments at times or under conditions favorable to success with the chemicals and plants concerned. In this connection, the plants' stage of growth and also the extent of moisture in the environment are noted in the table.

CONCLUSIONS

Factors Affecting Success with Herbicides

During the course of the investigations, it became apparent that the effectiveness of hormone herbicides, such as the various 2,4-D derivatives, and non-hormone agents, such as Ammate, is likely to be limited by conditions in the plants or in their environment. Moisture, temperature, stage of plant development, or the plant's period of greatest susceptibility to shock may determine whether or not a particular spraying will be successful. The significance of these factors in determining results was obtained in preliminary, small-plot tests and the information was used in subsequent larger-scale applications.

Ammate and 2,4-D gave more uniform results in aquatic and wet situations than they did in drier sites. Presumably this was due to the uniformity of water or moisture in the immediate environment. In relatively drier sites, variation in moisture may limit the predictableness of results of herbicide treatment. Since Ammate has the property of attracting moisture to itself, this resulted in the persistence of a readily-absorbed aqueous solution on sprayed foliage. In the case of 2,4-D treatments, wet habitat generally induces a more active physiological condition in plants which in turn causes better distribution of the hormone type of reaction.

Non-hormone herbicides such as Ammate can be used most effectively when treatments cause maximum shock to the plant. Previous studies on plant control by cutting at Reelfoot Lake (Steenis and Cottam, 1945) and elsewhere have indicated this vulnerable stage of plant growth.

There are several requirements to be considered when using the hormone type of control agents, such as 2,4-D. Best results were obtained during periods when temperature remained 70°F. or higher. In wet environment, vegetation generally was most vulnerable when actively growing and close to maximum foliage. In terrestrial habitat, treatments were usually more effective during an earlier stage of growth if correlated with ample soil moisture. Disregarding any of these factors may severely limit success.

Effectiveness of the Chemicals Used

In appraising the usefulness of different chemical agents as herbicides, consideration was given to the advantages and disadvantages of oil and water as carriers. If light oils, such as kerosene, are used, no wetting agent is required. Oil-carried control agents do not wash off readily and therefore can be used to advantage in treating aquatic plants. On the other hand, some herbicides are not soluble in oil. Furthermore

the use of oil adds to the cost of treatment and to the bulk that has to be transported. When using water-carried herbicides in swamps, marshes, and other aquatic areas, water required is readily available locally although it may have to be strained before using.

Water-carried herbicides often require a wetting agent or spreader. Examples of concentrations of "Tergitol Wetting Agent 4" needed when spraying Ammate are: .1+% for most vegetation, .2% for cattail, and .3% for lotus. Commercial 2,4-D formulations have had a spreader added to them, and therefore may not require addition of wetting agent except in treating the more repellent leaf surfaces. In such instances. 2% of Tergitol Wetting Agent 4 may be necessary. With reference to other spreaders the amount required will vary considerably depending on their wetting efficiency. When applying wetting agents, just enough should be added to cause adherence of the herbicide to the leaf surface. If too much is used, too great a dispersion of herbicide will weaken the effect of treatment.

Ammate

As indicated in Table 1, Ammate is effective on a wide variety of plants, both woody and herbaceous, at strengths of about 15% or ¾ of a pound to a gallon of water. Higher concentrations yield more positive results but the stronger dosages also involve greater danger to useful plants that may be in the vicinity. Besides its other merits, this chemical is reasonably economical. Care must be exercised when Ammate is contained in copper, brass, or bronze equipment since it will corrode these metals unless they are rinsed thoroughly after use.

2,4-D

Like Ammate, this chemical, in its various formulations, is economical, readily available and is effective on a wide variety of plants (see Table 1).

Different derivatives of 2,4-D of the same (acid equivalent) concentration have yielded similar results in marsh and water areas. Probably high humidity and heavy dews in this type of habitat allow the various 2,4-D formulations to be equally absorbed by plants. This fact is of practical significance since the commercial sodium salts of 2,4-D are considerably cheaper than the esters. In terrestrial habitats, more effective results have been noted from using 2,4-D esters because they dry down to an oily liquid which penetrates plant tissue more readily than 2,4-D salts. In comparatively dry sites, the salts incline to remain as inactive dry solids.

The selective action of 2,4-D on plants (controlling some and not affecting others) offers possibilities of special usefulness in mixed plant communities. For example .2% 2,4-D readily destroyed cocklebur but caused little or no effect on the largeseed smartweed. Van Overbeek and Velez (1946) divided weeds into four classes based on their sensitivity to 2,4-D.

Combination Treatment with Ammate and 2,4-D

A series of plots were sprayed with a mixture of 2,4-D and Ammate on the theory that the initial abnormal growth caused by the hormone herbicide might pave the way for more effective poisoning by the non-hormone component. This method showed no advantages. G. F. Miles of the DuPont Company re-

ported similar results. Since the vulnerable periods for these hormone and non-hormone chemicals commonly occur at different stages of plant development, two successive treatments, first one with 2,4-D and, later in the season, one with Ammate, were tried on hard-to-kill vegetation. Sprout growth in a recently cut-over site of mixed hardwoods and cypress, was sprayed with 2,4-D (.6%) in late June, and Ammate (¾ lbs. to a gallon of water) was applied during the first part of August. This dual-treatment procedure yielded more effective results than would two separate doses of 2,4-D or of Ammate. Likewise, spatterdock (*Nuphar advena*) at Reelfoot Lake treated with the above concentrations of 2,4-D in late May and Ammate in late June yielded over 95% control. This method appears to deserve further trial.

Other Chemicals

Atlacide, a Chipman Chemical Company product containing chloric acid and equivalent in calcium, showed ineffective results on woody growth and lotus. When applied to giant cutgrass, fair success was obtained when used at a concentration of one pound to a gallon of water.

Sodium arsenite as prescribed in Pessin's injection treatment of scrub oak was not clearly successful on willow. Sodium arsenite spray was effective in controlling giant cutgrass, but the extremely poisonous nature of this compound renders its use dangerous to the operator and to other forms of life.

There is need for herbicides that can control grasses and other plants which are not readily affected by 2,4-D. Such an agent could be of considerable value if it had selective characteristics. Derivatives of phenyl carbamate have been reported to cause adverse reaction on some of the grasses, particularly grains, but experiments with these chemicals on marsh vegetation were not successful. Promising results on the control of blade-leaved species were obtained when using chlorophenyl allyl carbonate dissolved in kerosene. Over 95% control on giant cutgrass resulted from spraying 2% concentration of this chemical, and equivalent success on cattail was obtained with a 4% concentration. This compound is not available in commercial quantities. Results from 2,4,5-T were similar to those of 2,4-D, but were not so effective on willow. TCA (sodium trichloroacetate) is another recent chemical of considerable promise. Plot studies were not made with this herbicide.

SUMMARY

During four years of investigation on the use of herbicides to control pest plants in waterfowl habitat in western Kentucky and Tennessee, it was found that:

(1) Ammate at ¾ pound to a gallon of water and 2,4-D at .6% strength can, under selected conditions, be used effectively on many plants, including important pest species such as lotus, giant cutgrass and several woody species. For the greatest degree of success, application must be at certain stages of plant growth and certain environmental conditions.

(2) For non-hormone types of chemicals, such as Ammate, best results are likely to be obtained at the period when treatment causes maximum shock to the plant. Generally this is somewhat later than the optimum time for 2,4-D and, in many plants, occurs when the plant is fruiting.

(3) Best results with the hormone-type of herbicide, such as 2,4-D, were obtained during active vegetative growth and when foliage development is nearly maximum. Correlated with this optimum stage of the plant's development, the environment should be wet and the average temperature should be 70°F. or higher.

(4) Successive treatments of 2,4-D and Ammate made at periods when hormone and non-hormone herbicides are each most effective, were used on hard-to-kill woody sucker growth and on spatterdock. This procedure was more effective than double treatment with either 2,4-D or Ammate, and may show promise for controlling resistant vegetation.

(5) Effective application of herbicides in waterfowl areas requires procedures that will result in economical replacement of objectionable vegetation by more desirable plants.

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A PRELIMINARY STUDY OF COCCIDIOSIS IN OKLAHOMA QUAIL

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INTRODUCTION

There is no published record of the parasitic fauna of the bobwhite quail (*Colinus virginianus L.*) of Oklahoma. Because the bobwhite is economically the most important game bird in the state of Oklahoma, a study of its parasites was begun in March, 1948. Since coccidiosis has been incriminated in the literature as the most frequent cause of quail disease, a preliminary survey was conducted to determine the incidence of *Eimeria*, the cause of coccidiosis in gallinaceous birds. Duck and Fletcher (1943), in an ecological survey of the game animals of Oklahoma, state that parasitic diseases probably do not appreciably affect quail populations. This conclusion was based upon the fact that no sick or dead birds were found in the field operations. No parasitic studies were made during the survey, however, and it seems that this conclusion needs checking with such studies. Coccidiosis causes a general unthriftiness, lack of appetite, and diarrhea, especially in young birds. A white, red-spotted intestine is revealed at autopsy; and in some species yellow, cheese-like cores occur in the caeca. Unthrifty quail very likely

* The valuable cooperation of the Oklahoma Game and Fish Commission, especially of Mr. W. A. Gaines, superintendent of the Game Department's El Reno quail hatchery, as well as the helpful suggestions of Dr. J. Teague Self, are gratefully acknowledged.

would be caught by predators before death and therefore would be unlikely to come to the attention of survey workers.

REVIEW OF THE LITERATURE

The identity of *Eimeria*, the coccidian parasite which causes coccidiosis, or white dysentery, in game and domestic birds, has been known for more than seventy-five years (Tyzzer, 1929b). Until the appearance of Tyzzer's works (1927, 1929a) on the various species of *Eimeria*, little distinction was made among the various forms. Tyzzer (1929b) differentiated eight species which occur in domestic and game birds. The only species which he recorded as naturally infecting the bobwhite quail was *E. dispersa*, which he first described in this paper.

Stoddard (1931) in a survey of the Eastern bobwhite reported the incidence of coccidiosis in the southeastern states. The intensity of infection varied with the locality, but no epidemiologic correlations were made, except it was noted that in 1927, a year especially favorable to quail populations, there was a high incidence of infection. He also stated that the severity of infection in growing quail "is roughly in inverse proportion to their age." Venard (1933) found 47.8 per cent infection in sixty-seven bobwhites examined in Ohio. He identified three different species of *Eimeria* (*E. dispersa*, *E. acervulina*, and *E. tenella*).

The genus *Eimeria* of the California quail (*Lophortyx californica* Shaw) has been studied extensively by various workers. Henry (1931) identified three species (*E. mitis*, *E. tenella*, and *E. acervulina*) from this bird. However, Tyzzer *et al.* (1931) questioned the identity of *E. tenella* since Henry did not observe the large second generation schizonts of this form. O'Roke (1928) in a survey of California quail reported no coccidia. Herman and Jankiewicz (1942) reported three species of *Eimeria* in both wild and captive quail, but did not name the species observed. Further work by Herman, Jankiewicz, and Saarni (1942) upon one hundred and one birds revealed eighty-nine infected, the highest percentage of infection being evident in females. An analysis of monthly incidence showed a decrease from April to August. Another study (Herman and Chattin 1942a) correlated this monthly changing incidence with the food of the birds, observing that infection was lowest when seed-food was most abundant. Herman and Chattin (1943b) found a similar correlation in some of the birds studied on the Dunes Lakes area of California. These authors also showed "that there is a variation in the intensity of infections within a single area at different periods as well as difference between areas."

Stoddard (1931) reported quail which apparently died of coccidiosis and observed that young quail were more susceptible than older birds. Tyzzer (1929b) did not investigate the pathogenicity of *E. dispersa*. Henry (1931) ascribed pathogenic characters to *E. tenella* and *E. acervulina* in California quail. Venard (1933) observed no pathological conditions in birds infected with *E. dispersa*. In birds infected with *E. acervulina* and *E. tenella* pathologic conditions were present when the infections were heavy. Herman, Jankeiwicz, and Saarni (1942) state that coccidiosis was the cause of death in a number of young

birds autopsied. Mr. W. A. Gaines, superintendent of Oklahoma's El Reno hatchery, stated that in "some seasons" birds at the farm suffer from coccidiosis, the symptoms of which he accurately described.

METHODS AND OBSERVATIONS

This paper reports the incidence of *Eimeria* in 22 wild, 2 released hatchery, and 32 captive bobwhite quail, as well as 8 captive scaled quail, *Callipepla squamata pallida* Brewster. Data are based upon sixty-four fecal samples from adult birds and six laboratory birds one month old. Collections were made during February and April, 1948. The material from wild birds and released hatchery birds (released Oct. 20, 1947, see Table 1 for number of each kind) was collected on the Robberson Ranch, Mustang, Canadian County, Okla. The collections were made concurrently with a study of the relative survival values of released hatchery and wild quail conducted by the State Game and Fish Department. The major range of the birds under investigation was post oak-blackjack oak woodland and tall-grass prairie. Native and cultivated seeds apparently made up the major portion of their winter diet.

The hatchery birds examined were not from the breeding stock, but were surplus. On the farm these are kept in wire-bottomed pens, with their food and water in feeder trays which can be reached only by the beaks of the birds. Sand and grit are placed inside the pen in a wooden box, and the birds can scratch freely in this material. In view of the low intensity of infection in these birds, the scratch box, a theoretically possible source of infection, seems to be of slight actual importance in this connection, probably because the oocysts are soon dried and become less infective (Benedetti, 1944).

TABLE 1.—INCIDENCE OF COCCIDIOSIS IN 64 OKLAHOMA QUAIL

Kind of Quail	No. Exam.	No. Infect.	% Infect.	Intensity Index
Released hatchery (bobwhite)	2	2	100	6.5
Captive (bobwhite)	32	17	53.1	11.7
Captive (scaled)	8	0	0	0
Wild (bobwhite)	22	7	31.8	89.6
Female bobwhite	27	15	55.5	46.9
Male bobwhite	29	11	37.9	12.4

The wild birds were captured in traps modeled after Stoddard's (1931) and placed in individual compartments of chick mailing boxes until droppings were obtained. Each sample was then placed in a screw-cap vial and covered with 2.5 per cent potassium bichromate (Herman, *et al.* 1942). The material from game farm birds was collected similarly.

Each sample was centrifuged according to the zinc sulfate flotation method of Faust, *et al.* (1939). The "Intensity Index" (see Table 1) was calculated by averaging the number of oocysts found in each group of birds *i.e.*, the average number of oocysts per infected bird per 18 mm. coverslip. This index permits a rough comparison of the relative degree or intensity of infection in different groups. The comparison is necessarily a crude one, partly because the size

equivalence of the fecal samples was judged by eye, and especially because of the fact that the rate of oocyst elimination varies at different times even in the same bird (Herman and Chattin, 1943b). Because of the variable rate of elimination of oocysts, weighing probably would not provide appreciably more reliable comparisons.

In order to identify the species of parasite involved, six quail one month old, previously determined to be free of infection, were fed oocysts resembling those of *E. dispersa*. These birds were then placed in individual cages while the course of the infection was followed. Isolation of a pure strain was not attempted.

Oocysts were found in the droppings at the beginning of the fifth day of infection. These oocysts sporulated in twenty-four–thirty hours when placed in 2.5 per cent potassium bichromate. No well-defined polar inclusion was observed. Completely sporulated oocysts averaged 22.29×19.35 μ. The largest oocyst measured was 25.1×21.8 μ, the smallest 20.2×18.0 μ. The spores are large (16.1×7.3 μ), leaving little unoccupied space in the oocyst. These observations agree with those of Tyzzer (1929b) for *E. dispersa*.

On the sixth day two birds were killed and portions of the intestine were fixed in various fixatives, sectioned, and stained in iron hematoxylin. Measurements are of material fixed in f.a.a. (Lavdowsky's mixture). Measurements of the intestinal stages were made with a calibrated ocular micrometer.

The intestinal stages were found to develop superficially in the epithelial cells of the villi, being most numerous in the upper portion of the small intestine. Both the persistent, elongate trophozoites and the dimorphic schizonts, mentioned by Tyzzer as characteristic of *E. dispersa*, were observed. In our material schizonts were observed which measured 13.9×11.7 μ, while those containing sausage-shaped merozoites averaged 7×8 μ. Schizonts containing small ovoid merozoites were more numerous than those containing the sausage-shaped forms. The macrogametocytes averaged 15.7×12.8 μ, while the size of microgametocytes averaged slightly smaller, or 14.6×10.5 μ.

DISCUSSION AND CONCLUSIONS

The data collected in this study are not extensive enough to warrant positive conclusions. Table 1 shows that a higher percentage of females than of males was infected; also, the intensity of infection appears to have been greater in this sex. An oocyst count of four hundred for one female (the next highest count was eighty-five) exaggerates the intensity index for this sex. However, if this bird is left out of the calculation, the index remains higher for females, being 21.7 as compared to 12.4 for males. These data may not be significant on account of the small number of birds examined. However, they agree with some of the data of Herman and Chattin (1943a, 1943b). The farm quail showed a higher percentage of infection than the wild birds, but a lower average intensity. The lower intensity may be attributable to the fact that they were kept in wire-bottomed pens, which prevent the ingestion of large numbers of oocysts. The higher percentage of infection, on the other hand, may be explained by the fact that many birds were kept together, which would facili-

tate the spread of the infection. More work needs to be done before sound conclusions can be drawn.

On the basis of size and morphology of the oocysts and the character and position of the intestinal stages, at least one species involved in Oklahoma quail is considered to be *E. dispersa* Tyzzer. Tyzzer (1929b) reported that in his material schizonts containing sausage-shaped merozoites were more numerous than those producing small ovoid merozoites. The opposite is true in our material, the sausage-shaped forms being very rare. It should be noted that Tyzzer believed that he was dealing with more than one strain. Also, probably more than one strain is present in our material. Therefore, the relative numbers of the two kinds of schizonts might depend upon the relative proportion of the strains present. There may be an alternating cycle between the schizonts, which would vary the relative abundance of the two forms. Our data together with those of Tyzzer suggest the presence of more than one strain in any natural culture of *E. dispersa*.

Several problems have been suggested by this preliminary study. A need for more extensive study of the incidence of *Eimeria* in both bobwhite and scaled quail is indicated. Infection studies should be made to determine the species found, the degree of pathogenicity, and the position in the intestine occupied by each species. Comparisons should be made between the number of oocysts found by the zinc sulfate flotation method and the degree of infection in the epithelium of the intestine. These would permit a more definite evaluation of the reliability of fecal examinations for the diagnosis of coccidiosis in quail.

Another line of investigation which may prove to be economically important is the determination of the time (*i.e.*, age of birds) and source of infection of young birds in quail hatcheries. Also, the epidemiologic relation between released hatchery birds and coccidia-free wild birds should be studied. It may be that it is better for quail to have light cases of coccidiosis than to be kept completely free of the infection. However, the immunology of the disease in quail must be studied before a decision on this point can be reached. A study of the relative efficiency of various antibiotics on the treatment of *Eimeria* in quail would not only be interesting biologically, but might prove useful in controlling outbreaks of the disease in captive birds. These problems have been investigated in the case of coccidiosis in chickens, but have not been adequately studied in connection with quail.

SUMMARY

1. An investigation was conducted to determine the incidence of *Eimeria* in Oklahoma quail.

2. Sixty-four quail were examined, and experimentally infected birds were used to determine the species of *Eimeria* involved.

3. Two released hatchery bobwhites were examined and both found positive. Twenty-two wild bobwhite quail were 31.8 per cent infected, while thirty-two captive bobwhites were 53.1 per cent infected. None of eight captive scaled quail was infected.

4. In the sample studied, females had both a higher percentage and higher intensity of infection than did males;

wild bobwhites had a higher intensity, but a lower percentage of infection, than captive bobwhites.

5. One species involved is identified as *E. dispersa* Tyzzer.

6. Some problems which may prove economically and biologically important are suggested for future investigation.

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CHEMICAL ANALYSIS OF SOME WILDLIFE FOODS IN CONNECTICUT[1]

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The study reported on here had its origin as part of a problem of determining the native wildlife food plants which could be used in a program of intensive wildlife management in Connecticut. Food value, as measured by proximate chemical composition, was felt to be one of the more important factors in the series of criteria set up for the evaluation. The specific objective of this phase of work was to attempt to correlate the chemical analysis of the wildlife food with reported utilization. Past studies of the food habits of wildlife have largely been aimed at providing gross quantitative and qualitative information. The factors of nutritive value, the effects on the wildlife organism, and the reasons for the choice of these foods have as yet to be as fully explored. In the wildlife field this approach has been attempted by Wainio and Forbes (1941), King and McClure (1944) and Treichler, Stow and Nelson (1946).

Collection and analysis of samples was started in 1941 and continued to 1947. In addition to samples collected in Connecticut, several were collected by the senior author while in the armed forces and later as Refuge Manager at the Bombay Hook Refuge in Delaware. The seeds and fruits reported on were collected when ripe when they would be used by wildlife. Cleaning was confined to removing such chaff, stems, etc., as would not be taken by wildlife in feeding so that analysis would be of material as used. The cleaned material was stored until air dry and then submitted for analysis.

Through the cooperation of Dr. E. M. Bailey and later Dr. H. J. Fisher of the Connecticut Agricultural Experiment Station at New Haven, proximate chemical analyses were made of the material submitted. The methods were those of "Methods of Analysis of the Association of Official Agricultural Chemists." Analyses of some of this material were previously reported by Bailey (1942) and Fisher (1947).

Table 1 gives the analyses of food material collected; Table 2 presents data for some species gathered to determine the effect of seasonal progression on chemical composition. The result of comparing the chemical analyses with a list of wildlife food plants rated according to reported use was inconclusive. In no case could utilization be correlated with nutritive value as measured by proximate chemical composition.

The values of this method of chemical analysis have previously been questioned by Atwood (1948). In addition, Bogart (1943) considered data on trace minerals essential in a complete nutritive study and Nestler (1946) pointed out the value of vitamins as components of wildlife foods.

[1] The authors are indebted to Dr. Ralph B. Nestler and other members of the staff at the Paruxent Wildlife Research Refuge for suggestions and criticisms during the preparation of this manuscript.

TABLE 1.—PROXIMATE CHEMICAL ANALYSES OF SOME WILDLIFE FOOD PLANTS

Scientific Name	Part Analyzed	Protein	Fat	Crude Fiber	N-Free Extract	Ash	Water
Sparganium eurycarpum	Seed	6.13	1.88	54.00	28.35	1.64	8.00
Potamogeton natans	Seed	7.00	7.02	42.46	36.33	1.01	6.18
Potamogeton pectinatus (Del.)	Seed	8.31	6.91	33.70	37.86	7.05	6.17
Ruppia maritima (Del.)	Plant	13.88	1.10	20.97	42.83	13.29	7.93
Najas flexilis (Md.)	Plant	21.44	0.65	15.30	52.44	8.14	2.03
Sagittaria latifolia	Seed	17.90	7.98	12.17	45.84	4.22	12.09
Alisma Plantago-aquatica	Seed	12.01	5.26	25.01	40.47	2.19	15.06
Vallisneria spiralis (Md.)	Seed	15.69	8.95	7.15	50.27	6.89	11.05
Paspalum setaceum	Seed	9.68	2.06	22.98	52.88	2.12	10.28
Panicum capillare	Seed	15.23	4.57	14.06	52.80	4.35	8.96
Panicum virgatum (Del.)	Seed	8.50	3.40	26.55	51.21	4.56	5.78
Echinochloa crusgalli	Seed	12.11	3.35	26.18	42.67	6.79	8.90
Setaria glauca	Seed	12.81	3.77	26.65	39.28	6.71	10.79
Setaria verticillata	Seed	14.55	5.08	13.33	49.95	6.29	10.80
Zizania palustris	Seed	13.24	1.48	4.35	68.23	2.72	9.98
Leersia oryzoides	Seed	11.38	2.55	9.58	65.59	3.14	7.76
Scirpus americanus (Cal.)	Seed	7.50	4.93	12.84	66.41	2.37	5.95
Scirpus robustus	Seed	7.81	3.96	13.08	64.48	2.98	7.69
Carex crinita	Seed	10.84	5.05	21.32	44.46	3.51	14.82
Carex stricta	Seed	11.06	3.98	21.40	48.96	4.28	10.30
Carex comosa	Seed	11.58	4.41	25.02	43.16	3.94	11.89
Carex lurida	Seed	8.14	3.08	25.66	41.88	6.54	14.70
Calla palustris	Berry	17.91	7.48	15.14	37.06	6.21	16.20
Lemna minor (Del.)	Plant	20.50	1.70	10.65	45.48	11.47	10.20
Commelina communis	Seed	18.20	1.43	7.04	52.89	6.38	14.06
Pontederia cordata	Seed	8.94	6.98	9.27	61.52	4.87	8.42
Allium tricoccum	Seed	17.56	10.46	5.73	44.50	1.98	19.86
Allium canadense (Ky.)	Seed	5.38	0.21	3.58	27.53	0.77	62.53
Smilacina racemosa	Berry	7.55	1.87	5.07	64.74	2.13	18.64
Maianthemum canadense	Berry	6.18	4.48	8.07	63.16	2.87	15.24
Polygonatum biflorum	Berry	9.47	5.13	5.87	59.47	2.91	17.51
Polygonatum commutatum	Berry	6.54	5.32	4.57	69.09	2.53	11.96
Polygonatum commutatum	Seed	12.50	7.10	4.38	67.23	1.63	7.16
Smilax herbacea	Berry	8.32	4.02	6.44	48.23	3.22	29.77
Iris versicolor	Seed	15.13	11.65	12.10	48.01	3.36	9.75
Urtica gracilis	Seed	24.75	17.75	14.88	27.33	10.34	4.95
Boehmeria cylindrica (Vt.)	Seed	19.69	18.58	23.70	21.77	8.18	8.08
Rumex crispus	Seed	12.94	3.84	19.32	46.84	2.78	14.28
Rumex obtusifolius	Seed	12.17	4.57	15.57	53.80	3.87	7.03
Polygonum pennsylvanicum	Seed	10.04	2.23	20.36	59.64	3.29	4.44
Polygonum acre (Cal.)	Seed	11.50	3.88	13.88	62.28	2.66	5.80
Polygonum sagittatum	Seed	19.88	5.60	4.88	59.00	1.60	9.04
Polygonum scandens	Seed	10.25	3.50	8.78	65.83	3.30	8.34
Chenopodium glaucum (Cal.)	Seed	20.13	8.30	11.12	45.50	2.78	12.17
Chenopodium album	Seed	13.25	5.55	14.63	46.02	7.17	13.38
Amaranthus retroflexus	Seed	15.82	5.86	12.14	47.91	4.11	14.16
Acnida cannabina (Del.)	Seed	22.19	12.19	6.10	45.74	6.57	7.21
Phytolacca decandra	Seed	10.61	6.64	10.19	55.46	3.26	13.85
Lychnis dioica	Seed	18.31	4.79	6.02	61.98	3.45	5.45
Lychnis alba	Seed	19.75	5.70	3.87	57.76	3.77	9.15
Saponaria officinalis	Seed	14.39	5.00	5.07	59.32	2.75	12.97
Portulaca oleracea	Seed	20.63	14.38	19.57	32.86	4.54	8.02
Thalictrum polygonum	Seed	21.23	22.19	17.61	23.15	3.59	12.23
Clematis virginiana	Seed	16.35	11.81	25.03	31.72	3.07	12.02
Actaea alba	Seed	16.18	26.08	13.77	30.24	7.55	6.18
Benzoin aestivale	Fruit	12.88	50.79	6.50	18.93	4.36	6.54
Benzoin aestivale	Seed	15.98	55.81	5.60	15.79	1.97	5.87
Lesquerella sp. (Cal.)	Seed	23.25	36.17	9.34	21.97	4.38	4.89
Thlaspi arvense	Pod	22.45	22.66	13.38	24.48	5.33	11.70

TABLE 1.—(*continued*)

Scientific Name	Part Analyzed	Protein	Fat	Crude Fiber	N-Free Extract	Ash	Water
Raphanus Raphanistrum	Pod	12.03	11.77	35.29	25.15	5.06	10.71
Brassica nigra	Pod	19.45	15.23	15.16	35.70	4.98	9.48
Geum strictum	Seed	10.45	16.26	16.26	38.53	3.88	14.62
Rubus allegheniensis	Fruit	7.93	7.20	20.45	48.80	3.74	11.88
Prunus serotina	Fruit	6.95	3.65	20.00	53.88	2.15	13.37
Cassia nictitans	Seed	33.21	3.35	6.80	44.73	4.88	7.03
Desmodium nudiflorum	Seed	22.91	3.59	22.68	35.68	4.35	10.99
Lespedeza virginica	Seed	26.65	3.54	19.34	36.92	3.41	10.14
Lathyrus maritimus	Seed	31.75	1.65	8.97	50.52	2.87	4.24
Apios tuberosa	Seed	24.83	10.19	5.30	30.81	7.00	21.97
Amphicarpa monoica	Seed	29.79	10.05	12.63	32.17	3.57	11.79
Euphorbia marginata	Seed	15.75	18.32	32.72	17.25	10.04	5.92
Evonymus sp.	Fruit	12.06	42.56	6.71	31.24	3.90	3.53
Abutilon Theophrasti (Del.)	Seed	19.81	16.19	18.90	32.62	5.68	6.80
Hibiscus Moscheutos	Seed	19.94	10.88	20.27	36.93	4.25	7.73
Oenothera biennis	Seed	18.61	22.32	19.05	22.73	6.72	10.57
Circaea lutetiana	Seed	13.35	10.22	20.49	35.06	6.28	14.60
Aralia nudicaulis	Fruit	8.88	8.11	23.28	42.36	4.81	12.56
Sium cicutaefolium	Seed	19.91	12.40	15.29	32.14	5.29	14.97
Angelica atropurpurea	Seed	23.99	13.12	18.84	27.47	6.75	9.83
Nyssa sylvatica	Fruit	4.77	15.18	8.20	56.35	4.46	11.04
Daucus Carota	Seed	17.6	12.22	24.87	28.78	5.77	10.76
Cornus florida	Fruit	6.62	11.50	31.79	35.01	5.90	9.18
Cornus florida	Pulp	8.44	23.95	13.93	43.12	4.73	5.83
Cornus florida	Seed	4.50	2.91	41.95	40.22	4.06	6.36
Vaccinium corymbosum	Fruit	8.95	7.20	11.74	53.79	3.27	15.05
Steironema ciliatum	Capsule	10.81	5.67	20.98	50.56	5.08	6.90
Asclepias incarnata	Seed	31.54	21.03	12.87	21.84	3.21	9.51
Ipomoea hederacea (Del.)	Seed	17.31	11.85	17.00	43.61	3.83	6.40
Ipomoea purpurea (Ky.)	Seed	22.00	10.74	11.60	41.77	4.14	9.75
Cuscuta arvensis	Capsule	8.95	3.14	15.31	56.90	2.31	13.39
Lappula virginiana	Seed	8.88	13.10	11.12	49.81	10.27	6.82
Nepeta Cataria	Seed	18.00	5.08	23.37	44.71	3.29	5.55
Galeopsis Tetrahit	Seed	18.28	29.05	24.20	13.43	4.98	10.06
Monarda fistulosa	Seed	19.83	17.36	26.58	21.21	6.66	8.36
Solanum Dulcamara	Fruit	14.01	11.30	17.84	39.83	5.63	11.39
Datura Stramonium	Seed	17.88	15.76	42.37	16.33	3.11	4.55
Verbascum Thapsus	Seed	17.56	19.54	25.18	27.00	3.55	7.17
Plantago major	Seed	17.03	7.62	13.68	45.94	4.60	11.23
Mitchella repens	Berry	7.34	7.36	20.96	38.59	3.40	22.35
Cephalanthus occidentalis	Seed	8.90	8.66	34.23	34.59	2.83	10.92
Lonicera tatarica	Fruit	6.06	5.65	5.28	68.48	3.57	10.96
Symphoricarpos orbiculatus	Fruit	6.13	3.36	18.34	67.83	3.89	0.45
Viburnum acerifolium	Fruit	8.65	13.07	20.54	44.24	3.74	9.76
Viburnum Lentago	Fruit	5.70	10.19	9.30	61.60	2.43	10.78
Viburnum Lentago	Pulp	2.50	5.14	5.94	75.84	2.69	7.89
Viburnum Lentago	Seed	8.63	12.68	11.70	57.30	2.34	7.35
Sambucus canadensis	Fruit	8.31	13.31	20.78	42.70	5.31	9.59
Ambrosia trifida	Seed	20.11	23.52	29.52	16.45	3.11	7.29
Ambrosia artemisiifolia	Seed	15.14	8.89	36.48	23.24	4.07	12.18
Helianthus annuus	Seed	20.11	23.52	29.52	16.45	3.11	7.29
Helianthus scaberrimus (Okla.)	Seed	18.69	17.89	27.95	26.96	2.71	5.80
Bidens frondosa	Seed	21.56	11.25	18.88	28.23	5.35	4.73
Arctium minus	Seed	9.46	10.21	16.97	21.52	3.19	38.65

Unless otherwise noted, material was collected in Connecticut.

TABLE 2.—COMPARISON OF FOOD VALUE IN FALL AND WINTER SEEDS AND FRUITS

Name	Season	Protein	Fat	Crude Fiber	N-Free Extract	Ash	Water
Smartweed	Fall	10.04	2.23	20.36	59.64	3.29	4.44
Polygonum pennsylvanicum	Winter	6.75	3.02	14.13	59.28	1.68	15.14
Poke	Fall	10.61	6.64	10.19	55.45	3.26	13.85
Phytolacca decandra	Winter	15.71	9.88	13.71	49.90	2.67	8.13
Carrion-flower	Fall	8.33	4.02	6.44	48.23	3.22	29.71
Smilax herbacea	Winter	10.02	6.40	10.38	45.94	3.00	24.26
Ragweed	Fall	15.14	8.89	36.48	23.24	4.07	12.18
Ambrosia artemisiifolia	Winter	18.23	8.54	24.71	31.83	4.87	11.82
Pigweed	Fall	13.25	5.55	14.63	46.02	7.17	13.38
Chenopodium album	Winter	12.54	6.46	18.07	42.69	3.68	16.56
Dock	Fall	12.94	3.84	19.32	46.84	2.78	14.28
Rumex crispus	Winter	9.33	1.71	21.40	50.47	3.27	13.82
Avens	Fall	10.45	16.26	16.26	38.53	3.88	14.62
Geum strictum	Winter	15.12	15.54	18.43	34.08	3.39	13.44
Dodder	Fall	8.95	3.14	15.31	56.90	2.31	13.30
Cuscuta arvensis	Winter	12.00	2.81	19.14	52.98	2.00	11.07

That soil and soil water are basic factors in determining the nutritional value of plant material was pointed out by Midgley (1937) in a study of the modifications of chemical composition of pasture plants by soils. He states flatly that, "if the soils are high in available plant nutrients, it will be reflected in the chemical composition of the plants." Albrecht (1944) points out special interrelationships of soil fertility and animal life. Adams, Boggs and Roller (1937) found that yield and chemical composition were affected by various fertilizer ratios. Lund and Sandstrom (1943) state that there may be a great difference in the nature of the protein laid down in the seed during a dry year and during a year when the rainfall is normal. Daniel and Harper (1935) found an inverse ratio in the calcium and phosphorus content of native grasses and alfalfa in wet and dry years. Browne (1938) found that an increased water supply led to an increased absorption of mineral matter.

It is apparent, from the references cited, that only the most general conclusions can be drawn from analyses such as those made for this study. The absolute measure of the use of a given food by wildlife and the value of that food to the species using it would necessitate exact data on a considerable number of variables. The correlation attempted in this study, of chemical analysis and reported food use reveals that further research is required to explain even such superficial data. The majority of the food habit studies have been made during the fall and winter. During this period the birds are sometimes forced by human activity to use other than preferred foods. Stoudt (1944) reporting on mallard ducks in Minnesota points out that the ducks are "burned out" of the wild rice beds and feed on second choice pondweeds.

It may be that, during the gunning season, upland-game birds tend to remain in heavy cover and feed on available foods found there rather than risk foraging for preferred foods.

Two interesting points were brought out in the study which may merit further research. One is that when our data for particular plants, and in some cases for all representatives of a genus, were compared with data from other studies, a similarity of chemical composition was evident. This may mean that for many plants the proximate chemical composition as measured here is essentially similar over the entire range of the plant. It could indicate somewhat similar values for different species of the same genus.

The second point concerns the findings of Guilbert, Mead and Jackson (1931) and LeClerc and Breazeale (1909), where it is pointed out that leaching may cause the loss of nutritive value and inorganic constituents in seeds and plants. From the data presented in Table 2, no significant difference was noted in chemical composition as a result of seasonal progression.

It is evident that a more extensive series of tests must be applied, including controlled feeding of wildlife species, to determine the nutritional or biological value of each food for each species. Whether or not such admittedly expensive and time-consuming projects would add materially to practical wildlife management would depend upon the intensity of the management practices required to supply a harvestable surplus.

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MALTHUS—A REVIEW FOR GAME MANAGERS[1]

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Thomas Robert Malthus is generally known to have influenced biology decisively by his influence on Darwin. But now that the study of animal populations is becoming an increasingly important aspect of biology, it is desirable to examine again Malthus' original principle of population. The game manager in particular is concerned every day with the population problem and can profit from a study of Malthus.

Malthus first published his "Principle of Population" in 1798, apparently in a brief pamphlet. A second and greatly expanded edition was soon published (1803) and followed by several others. Apparently the sixth edition (1826) contained the last revisions. A ninth edition was published posthumously in 1888 and is the one usually found in libraries.

Before analyzing Malthus' contributions of special interest to game managers, let us rapidly summarize the book and his principle. Book I is concerned with the "checks to population in the less civilized parts of the world and in past times." The first 2 chapters state Malthus' basic principle that there is "the constant tendency in animated life to increase beyond the nourishment prepared for it" or "the constant tendency to increase beyond the means of subsistence." He then points out that although humans increase as 1, 2, 4, 8, 16, 32 . . . , the means of subsistence increases only as 1, 2, 3, 4, 5, 6 . . . . He quickly states that the ultimate check is food but it is never the immediate check except in famine. The immediate check is "all those customs and diseases generated by a scarcity of the means of subsistence." Malthus then divides these checks into the preventive (birth control) and the positive (every cause which contributes to shorten the life of man). These checks are "all resolvable into moral restraint, vice, and misery." Malthus, of course, does not use the words "birth control" but comments that the preventive check is voluntary in man and involuntary in other species. Moral restraint refers obviously to "planned parenthood"; vice refers to the promiscuity and other sexual aberrations which result in a reduction in birth rates; misery refers naturally to lack of adequate food and shelter. Malthus further states that the

[1] Contribution from the Rodent Ecology Project of the Department of Parasitology, School of Hygiene and Public Health, The Johns Hopkins University. The work reported in this paper was conducted under a grant from the International Health Division of the Rockefeller Foundation.

sum of the preventive and positive checks forms the immediate check to the population. These two checks vary inversely and are in constant operation. He summarizes his propositions as follows: "1. Population is necessarily limited by the means of subsistence. 2. Population invariably increases where the means of subsistence increase, unless prevented by some very powerful and obvious checks. 3. These checks, and the checks which repress the superior power of population and keep it on a level with the means of subsistence, are all resolvable into moral restraint, vice, and misery."

After this statement of his principle, Malthus in the rest of Book I describes the checks to population in primitive populations, such as American Indians, Africans, South Sea Islanders, Chinese, and the Greeks, and Romans. There is a fascinating recital of marriage customs, infanticide, disease, and war in these populations. He gives ample evidence that the preventive and positive checks develop from lack of the means of subsistence and constantly act to remove the redundant population.

Book II describes the checks to population in the states of modern (18th century) Europe and presents some interesting quantitative data. For example, he shows that the birth rate in Prussia increased strikingly after an epidemic of plague in 1709–10 and was roughly inversely proportional to the population.

Books III and IV are of keen interest to every citizen because they discuss various systems of artificial equality, government relief, crop bounties, obligation to practice moral restraints, charity, and many other human problems which, however, are beyond the scope of this review for game managers. But as citizens, game managers would profit by a consideration of Malthus' predictions.

Now let us consider the parts which are of special interest to game managers. Malthus clearly understood that populations follow definite laws when he says "And since the world began, the causes of population and depopulation have probably been as constant as any of the laws of nature." He recognized that in increasing populations, the gain is inversely proportional to the population as is now found in quail, grouse, and many fish.

Since Malthus wrote at the beginning of the spectacular rise of human population during the last 200 years, he was aware of many aspects of the laws of stable populations. For example, he noted that in Dutch villages the marriages (hence births) were proportional to the deaths and that "except where some sudden start in agriculture enlarged the subsistence, an increase of marriage must be accompanied by an increase in mortality." These observations have particular pertinence for those who would introduce game animals into an area without "enlarging the subsistence."

Malthus also was aware of some of the consequences of different age compositions. He noted that in a stable population an increase in the unmarried does not diminish the population, but merely diminishes mortality because deaths are not necessary to make room for children. Furthermore he recognized that the relative number of unmarried in a population does not indicate the absolute size of the population but

merely whether it is increasing, stable, or decreasing. Lastly, he recognized that after war, pestilence, or famine an old state resembles a new colony in its rate of growth and age composition.

In addition to appreciating many of the characteristics of the stability and growth of populations, Malthus understood the role of the various factors in limiting populations. He notes that "the only true criterion of a real and permanent increase in the population of any country is the increase in the means of subsistence." He is, however, fully aware that there may be low populations with a high standard of living or high populations with a low standard. Game managers will at once recognize this as the alternative of a few big fish or many little fish in a pond. Malthus also was aware of the importance of environment in preparing a population for the action of other checks. He believed that a high mortality in Sweden was due to undernourishment and he commented, "It cannot escape observation that an insufficient supply of food to any people does not show itself merely in the shape of famine but in other more permanent forms of distress and in generating certain customs which operate sometimes with greater force in the prevention of a rising population than in its subsequent destruction." Our modern game managers have ample evidence that inadequate food supplies render a species susceptible to various mortality factors.

Malthus also noted that improvement of the food supply had more effect than reducing infant mortality for he said "if the government (Sweden) would remove impediments to farmers it would be better for the population than 500 foundling hospitals." Again he notes the tendency of a population to build up to the limit of the area. "Such an extraordinary proportion of births (in Scotland) caused evidently by the habit of emigration shows the extreme difficulty of depopulating a country merely by taking away a part of its people. Take but away its industry and the sources of its subsistence and it is done at once. . . . And it cannot be doubted that the drain (emigration) tends greatly to relieve the country and to improve the conditions of those who remain." Thus Malthus anticipated the findings of the fisheries men who recommend intensive fishing to get the most favorable yield.

At the time Malthus wrote the larger predators on humans were extinct but the bacterial predators frequently ravaged whole countries. Malthus keenly appreciated some of the effects of predation. He noted that an epidemic is succeeded by healthfulness because the weak are killed and there is more room and food for the survivors and that among the causes of epidemics are crowded houses and insufficient food. He also noted how rapidly a population recovers after an epidemic for the effects of the dreadful plague of London in 1666 were not visible 15–20 years later.

Lastly, Malthus noted the great effects of competition among individuals and tribes. He remarked that "neighboring nations live in perpetual hostility. The very act of increasing in one tribe must be an act of aggression on its neighbors." In Ireland the increase of population after the introduction of the potato was followed first by disease and then by civil war and commotion. The social structure is also important since

he calls a tyrannical government, "—that greater depopulator than either wars or plagues."

Malthus of course did not completely anticipate our present concepts about populations. He did not recognize the difference between density-dependent and density-independent factors. While he was dimly aware that social structure of the population was important he apparently did not consider the possibility that a change in social structure may result in a change in population in a given environment. For example, birds which lose their territorial requirements to associate in coveys can have a relatively higher population than can a species which persists in its spatial demands. Similarly, Malthus was not aware of the need of animals for space as such (territory) and neglected this limiting factor. Finally, Malthus did not clearly state the consequences of predator (disease) control as such. However, from his statements about the means of subsistance limiting the redundant population it is certain that Malthus realized that a reduction of the mortality due to predation would be matched by an increase in the mortality due to other causes in a stable environment.

In conclusion it may be said that Malthus shrewdly analyzed many aspects of the principles of game management. He found that the gain of a population was inversely proportional to the population and that mortality factors constantly act to keep a redundant population within its means of subsistence.

REPORT ON THE RESULTS FROM TROUT STOCKING IN THE DEERFIELD RIVER[1]

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INTRODUCTION

To supplement information on the results of stocking legal-sized trout in streams and rivers of Massachusetts, creels were sampled in the 1946 and 1947 seasons on the Deerfield River. Previous studies on the Westfield River (Nesbit and Kitson, 1937) indicated that spring stocking was about five times more effective than fall stocking; and on the Quaboag River (Swartz, 1944) that results varied considerably with different species of trout. It is interesting to note that the average recovery in the current season was only about 12 per cent on the Westfield River where internal tags and voluntary reports were depended upon, whereas the recovery averaged 62 per cent from the Quaboag River where trout were marked by fin-clipping and official inspection made of all creels. A preliminary report on the results of the latest study is presented in the following sections.

The Deerfield River arises in central

[1] This investigation was made while the writer was employed by the Massachusetts Department of Conservation. Acknowledgment is made to Mr. Howard Schuck of the Fish and Wildlife Service for assistance in the design of the 1947 sampling method.

Vermont and flows in a general southerly direction into northwestern Massachusetts. A series of dams, owned by the New England Power Company, act to isolate various sections of the river. The main purpose of the dams is to obtain head for power generation rather than storage. This latter function is provided by two large reservoirs in Vermont which release water in accordance with daily power requirements. In relation to the trout fishing, these operations have three important effects: first, the river is subject to considerable daily fluctuation; second, low flows in summer are augmented; and finally, summer temperatures are lower than they were under natural conditions.

The uppermost 20 miles of the river in Massachusetts was designated as the experimental site. This reach is marked by power developments at both ends with unbroken river between. Because this reach is generally considered to furnish the best trout fishing and is isolated from the reaches above and below, it was well suited for the purposes of the investigation. Records from the U.S.G.S. gauge, located within the section in the town of Charlemont, indicate that flows exceed 600 second-feet 50 per cent of the time and 400 second-feet 75 per cent of the time. Temperatures remain generally below 75 degrees F. except for periods of extended drought when reservoir discharge is reduced. Several trout streams enter the river in the test section, all of which are freely accessible from the river. Among the more important are: Pelham Brook, Cold River, Chickley River, Avery Brook and Clesson River. Legal-sized trout are planted annually in these streams and the possibility of movement from tributaries to the river and vice versa exists. Thus, a complicating factor is introduced in the analysis of catch data.

Special regulations are in effect on the Deerfield River. Among the more important are a minimum legal length of nine inches, a daily bag limit of six trout, and restriction to the use of artificial lures in a reach that constitutes the upper half of the test section. The open season extends from April 15 to July 31.

METHODS

Numbers of fish planted.—In 1946, 12,955 trout, ranging in length from 9 to 13 inches, were planted in the test section. Of this total, 7,840 were brook trout, 3,050 were brown trout, and 2,065 were rainbow trout. With the exception of 400 brook trout and 100 brown trout planted May 23, all of the fish were released during the month of March and prior to the open season. The three species of trout were distributed to all accessible locations but were not planted in the same proportion in each location.

In 1947, the stocking totaled 13,800 and was comprised of an equal number (4,600) of brook trout, brown trout, and rainbow trout. As in 1946, the fish ranged in length from 9 to 13 inches and were introduced prior to the open season. The test area was divided into seven sections, each with a length of about three miles. With minor exceptions, equal numbers of each of the three species were planted in each section simultaneously. The stocking record is summarized in Table 1.

Marking.—In 1946, approximately 20 per cent of the trout planted were

TABLE 1.—SUMMARY OF PLANTINGS OF HATCHERY TROUT IN THE DEERFIELD RIVER, 1946 AND 1947

	Brook Trout	Brown Trout	Rainbow Trout	Total
1946	7,840	3,050	2,065	13,955
1947	4,600	4,600	4,600	13,800
				26,755

marked by removing the right pectoral fin. The following year, however, all of the planted fish were marked. Except in the case of two small lots of rainbow trout, the 1947 plant was marked by removing the left pelvic fin. In order to obtain data on rainbow trout migration, one lot of 160 trout, marked by removing the left pelvic and adipose fins, was planted in Section I; and a second lot of 200 trout, marked by removing the left pectoral and adipose fins, was planted in Section IV.

Operation of the census.—The chief objectives of the study were to compare the contributions made to the catch by planted and wild trout; and to compare the returns of the three species of trout. In view of the resources available for the investigation it seemed advisable to sample the catch rather than attempt to record the total. Such an attempt would have certainly met with failure owing to the length of the test section (20 miles) and the great number of roads serving the area. In 1946, anglers were selected at random each day and their catch inspected and recorded by personnel officially designated to perform this function. This practice appeared essential in view of the many anglers who were unable to identify the species of trout and overlooked the clipped fin.

The sampling was more or less haphazard in the 1946 season and, consequently, it is not known what part of total fishing effort was sampled. In order to obtain this information, methods were refined the following season. A stratified random sampling system in relation to sections and periods of the fishing day was devised and adopted.

The creels of all anglers encountered within the designated time and section were checked whether or not fishing was completed. A correction factor, based on completed catches, was later applied to catches of anglers who had not completed fishing when checked, so that the total daily fishing effort and catch could be estimated for each section.

RECOVERIES

The number of anglers checked in the 1946 season was 956. These men fished a total of 4,364 hours, and caught a total of 1,455 trout at the average rate of 0.33 fish per hour. In the 1947 season, 3,764 anglers were checked. They had fished a total of 10,230 hours and had caught a total of 2,112 trout at an average rate of 0.21 fish per hour.

The contribution of planted fish to the catch.—On the assumption that marked and unmarked trout were caught in the same proportion as released, it is estimated that 1,284 trout in the 1946 aggregate sample were released in 1946. Thus, it may be stated that 88.2 per cent of the catch was comprised of hatchery trout planted in the same season. Since all trout were marked in 1947, it was possible to avoid the assumption that a certain portion of the unmarked fish were of hatchery origin. Thus, in 1947, 1,739 marked trout were recorded, representing 82.3 per

cent of the aggregate sampled recovery. From these figures, it is clear that trout planted in a particular year provide the bulk of the fishing in that year and that less than 20 per cent of the catch is comprised of wild fish and fish planted in previous years. In regard to the last category it is of interest to consider the relative contribution of fish planted in 1946 to the 1947 catch. It was estimated that only 30 trout, representing somewhat less than 1.5 per cent of the 1947 aggregate sample, were derived from 1946 plantings. Many investigators have reported the inability of hatchery trout to winter over successfully. The data from the Deerfield River support this conclusion.

The contribution of wild fish to the catch.—In 1946, 11.8 per cent, and in 1947, 16.2 per cent of the sampled catch were comprised of wild fish. An analysis of this component of the catch is presented in Table 2. It will be noted that

TABLE 2.—CONTRIBUTION OF WILD TROUT TO THE CATCH

Species	1946		1947	
	Number	Per Cent	Number	Per Cent
Brook trout	33	2.3	28	1.3
Brown trout	42	3.0	140	6.6
Rainbow trout	96	6.5	175	8.3
Total	171	11.8	343	16.2

wild rainbow trout ranked highest, and that the other two species maintained the same relative positions both years, with brown trout occupying an intermediate position and brook trout ranking lowest. While it would be of obvious advantage to foster the production of wild trout regardless of species, these data at least suggest that rainbow trout most merits such encouragement and brook trout, least. Mention was made earlier that the analysis of catch data from the main river was complicated by releases in tributaries. All three species were released unmarked in several of the tributaries and thus there is some possibility that a certain number might have descended to the river and entered the catch as wild trout. In view of the migration pattern that became evident in the Deerfield River, such movement would bias the data in favor of rainbow trout and brown trout and against brook trout. Final judgment on the relative importance of the various wild components must, therefore, be withheld until the relationship of tributary releases to river recoveries can be clarified.

Migration.—Observations on migration were incidental except for two lots of rainbow trout, marked in a manner to identify their planting location. Random creel samples, taken during the season on ten tributaries, furnished records of 140 marked trout. The preponderance of marked brook trout in this group is illustrated by the following analysis by species:

Brook trout	115
Brown trout	12
Rainbow trout	13

Evidence regarding the extent and direction of rainbow trout migration is meager but it does indicate that such movement is chiefly downstream. Only 14 rainbow trout, out of a total of 360 marked so as to identify the planting location, were recovered. Three were caught about three miles below planting, nine were caught about seven miles below planting, and three about ten miles below planting. None was re-

covered upstream. In this connection it is of interest to note that the lowermost planting was made two miles above the dam which marks the downstream end of the test area. This step was taken to minimize the loss of fish through migration into the powerhouse diversion or over the dam. Despite this precaution, brown trout and rainbow trout descended into this area and it appears probable that many passed over the dam or attempted to pass through the penstock. No systematic attempt was made to record the catch at the forebay situated immediately above the penstock but below the test area. Thus, the following summary of occasional records from the forebay catch represents only a small portion of the fish that were caught or passed through the area. This summary, however, is useful as an index of the relative movement of the three species of trout.

Species	*Number*
Rainbow trout	49
Brown trout	39
Brook trout	4

Efficiency of recovery.—One of the most important criteria in formulating an economical stocking program is the efficiency of recovery in the current season. Unfortunately, it is not known what part of the fishing effort was sampled in 1946 and therefore no reliable estimate of the total catch can be made. Nevertheless, a basis is provided in the marked fish recorded, to compare the relative efficiency of the three species. The recovery, expressed as percentage of the marked fish planted, is summarized as follows:

Species	*Per Cent*
Rainbow trout	13.0
Brown trout	12.6
Brook trout	8.0

On the basis of efficiency of recovery of marked fish in the current season, brook trout are inferior to the other two species. This is contrary to what might have been expected on the basis of observations in Massachusetts and elsewhere. A partial explanation, however, was forthcoming in the second season of the investigation.

In 1947, it was estimated that 9,400 anglers caught a total of 5,288 trout. Of this total, 4,336 were planted in 1947. This number represents a return of about 31 per cent on the 1947 stocking. To compare the relative efficiency of recovery, as in 1946, the recoveries of marked fish, expressed as percentages of the plant, are summarized as follows:

Species	*Per Cent*
Brown trout	35
Rainbow trout	32
Brook trout	26

As in 1946, brown trout and rainbow trout show a better return than brook trout. A clue to the poor return of planted brook trout in the river itself was obtained by the occasional checks made on its tributaries. A summary of the records thus obtained was presented in the preceding section and it will be recalled that brook trout far outnumbered the other two species. These records supplemented by verbal reports from anglers, indicate that many of the marked brook trout which had been released in the main river had shortly thereafter crowded into the tributaries and were easily caught. Consequently, it appears probable that brook trout would have ranked first in over-all recovery if the tributary catch had been recorded systematically and added to the river catch. Nevertheless, such lumping would have presented a decep-

tive picture in view of the object of the plantings to create fishing in the river. Fishing provided elsewhere not only partially defeated this purpose but also was wasteful and undesirable from a management standpoint. Legal-sized trout were planted in all tributaries capable of supporting them, yet, both these streams and others, considered too small to support adult trout on a year-round basis, received an increment from river plantings. In streams of the latter category, the "bath-tub" fishing that resulted was highly efficient perhaps, but of a type to be discouraged as a matter of policy. On the basis of these considerations, the three species are judged solely on their contribution to the river catch; accordingly, brook trout are ranked as the least effective.

TABLE 3.—AVERAGE NUMBER OF FISH CAUGHT PER HOUR SUMMARIZED BY WEEKS

Week Ending	1946	1947
April 21	0.22	0.24
April 28	0.36	0.24
May 5	0.33	0.19
May 12	0.30	0.17
May 19	0.25	0.30
May 26	0.43	0.23
June 2	0.37	0.20
June 9	0.46	0.29
June 16	0.37	0.23
June 23	0.43	0.20
June 30	0.84	0.18
July 7	0.33	0.09
July 14	0.43	0.06
July 21	0.52	0.02
July 30	0.43	0.04

Quality of fishing.—The quality of fishing provided by the Deerfield River as expressed by the average number of fish caught per hour was 0.33 in 1946 and 0.21 in 1947. This statistic is presented in Table 3 for weekly periods in the open seasons. In the 1946 season, there appeared to be little correlation between numbers of fish present and the catch. Apparently, fishing improved during the season to reach a peak in June. In July, it was still superior to fishing in the first two weeks of the open season. In 1947, there was no apparent trend in the quality of fishing until near the end of June. From this time until the end of July, the quality declined. Differences in temperature, water stages and other physical conditions between the two years are not of a magnitude to account for the relatively poor quality of July fishing in 1947 as compared to that of the previous year.

DISCUSSION

On the basis of data obtained in 1946 and 1947, it is clear that planted trout provide most of the fishing on the Deerfield River. Under present stocking methods, however, only a small part of the planting is recovered in the current season (31 per cent in 1947) and there is scarcely any carry-over from year to year. At present, the poor returns from planted fish and the low yields of native fish make for expensive but none the less poor fishing. It would be in the interests of economy, obviously, to encourage the production of native trout and to increase the efficiency of recovery of planted trout.

In one respect, at least, the encouragement of natural reproduction is being hindered. Under present laws, protection to spawning rainbow trout is being denied. Both in 1946 and 1947, a number of rainbow trout taken during the first three weeks of the open season (April 15 to May 5) were observed to be in a spawning condition. This situation is especially serious in view of the

indication that, of the various wild species of trout in the Deerfield River, only the rainbow trout makes a substantial contribution to the catch. If natural reproduction is a limiting factor, the native population would be benefited by affording protection during the spawning period. This could be provided by a later opening date, as, for example, May 15. A further advantage of such a change would be the opportunity it afforded to postpone the initial planting of hatchery fish to a time when conditions are likely to be more favorable for survival.

Despite the recognized value of staggered plantings made in the open season, this practice has not yet been adopted in Massachusetts owing to the inflexibility of hatchery schedules. These schedules are based on the release in the spring of the entire seasonal quota of trout in order to make way for the new crop of fingerlings and yearlings. These operations together with the early opening, April 15, result in a single planting in March when conditions are often poor and even hazardous for hatchery trout. It is probable that great losses occur in this period due to the prevalence of low temperatures, floods, ice and predation. In 1947, for example, temperature records in the period April 15 to May 8 ranged from 34 to 40 degrees Fahrenheit. Almost all trout caught in this period had empty stomachs and had deteriorated in condition, vigor, and appearance. Subsequent to this period, water temperatures gradually increased and stomach examinations disclosed that hatchery trout were foraging for themselves. As the season progressed, they could scarcely be distinguished from native trout in any respect. It seems reasonable to suppose that many more trout would survive to be caught if planted under more favorable conditions.

A further step toward more effective stocking might be achieved by using only the better producing species. It will be recalled that rainbow trout and brown trout were creeled more efficiently than were brook trout. The differences involved, however, were small and by exclusion of brook trout from future plantings only a minor economy can be anticipated.

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ESTABLISHMENT OF KOKANEE IN CRATER LAKE, OREGON[1]

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The kokanee (*Oncorhynchus nerka kennerlyi*), the dwarf, landlocked form of sockeye salmon, was found in Crater Lake, Oregon in 1939 and 1947, obviously as the product of natural reproduction. Previous published references by Hasler (1938), Hasler and Farner (1942), and Brode (1938) to Pacific salmon in Crater Lake have considered the silver or silverside salmon (*O. kisutch*) to be the only species present. National Park Service planting records, dating from 1910, list only the silverside salmon, brown trout (*Salmo trutta*) and rainbow trout (*Salmo gairdnerii*) as having been officially stocked in the lake. It is not known how or when the kokanee was introduced.

Crater Lake, four miles wide and six miles long, fills the caldera of an extinct volcano. It contains no visible outlets; the few insignificant inlets are short, steep cascades born from seepage high within the walls of the caldera. Before the first plants of trout were made in 1888 by William Gladstone Steel, it was devoid of fish life.

The kokanee is native to the Northwest, where it is known by many common names: little redfish, silver trout, kokanee, kikanning, silver salmon, Kennerly's salmon, Kennerly's trout, and walla. Dymond (1932, p. 42) mentioned the possibility "that some of these names are likely to be misleading, the term silver salmon, for instance, being also applied to the silvery form of the Kamloops trout and also to the coho or silverside salmon."

Hasler and Farner (1942) stated that the natural reproduction of silverside salmon in Crater Lake had been proven by scale readings, which indicated that salmon taken in 1939 and 1940 were from the 1938 and 1939 year classes. Since no salmon were planted in 1938 or 1939, these investigators assumed that the silverside salmon were the result of natural spawn.

Hasler and Farner were primarily interested in growth, age, and food studies and relied on others for the identification of the salmon with which they were working.

Silver salmon will occasionally spawn

[1] The authors wish to express their thanks and appreciation to: Dr. Carl L. Hubbs, Scripps Institution of Oceanography, who verified our identifications and critically reviewed this manuscript; to Dr. F. F. Fish, U. S. Fish and Wildlife Service, who furnished specimens collected in 1939; to Professor R. E. Dimick, Department of Fish and Game Management, Oregon State College; Dr. Arthur Hasler, Zoological Laboratory, University of Wisconsin; Dr. Donald Farner, Department of Zoology, Washington State College; Dr. Paul R. Needham, Department of Zoology, University of California; and Dr. George C. Ruhle, Park Naturalist, Crater Lake National Park and other National Park Service officials for their suggestions and assistance with this research.

in landlocked situations. Schultz (1935, p. 3778) reported that "in one small stream tributary to Lake Washington we have observed a small run of landlocked silver salmon breeding at the small size of about 12 inches." During investigations conducted for the Oregon State Game Commission in 1947, the junior author found landlocked *O. kisutch* in Lake of the Woods, Klamath County, Oregon. Scale studies revealed that the age of these specimens corresponded with known plants made by the commission. No evidence of natural reproduction of *O. kisutch* was discovered.

Needham (1940, p. 12), however, concluded that young hatchery-reared silver salmon planted in landlocked lakes will sometimes produce some excellent fishing but that this fish thus planted does not mature to spawn as they do in the ocean and hence offer only a temporary stock.

From Japan, Jordan and McGregor (1925) described a landlocked species of Pacific salmon, *O. ishikawee*, which apparently is a dwarf off-shoot from *O. kisutch*.

That kokanees survive by natural reproduction in closed bodies of water has been mentioned by Dymond (1932), Needham (1940), Dufresne (1946), Clemens and Wilby (1946), Schultz (1935), Jordan and McGregor (1925), Curtis and Fraser (1948), and others. That it was found in Crater Lake in 1939 and 1947, although no salmon have been planted since 1937, indicates that it has reproduced in this lake. Scale readings indicate that the fish taken in 1939 and 1947 are from the 1938 and the 1944 year classes, respectively.

Concerning this variation from the rule that Pacific salmon spend a portion of their life cycle in the sea, Dufresne (1946, p. 278) wrote that "no other of the five species of Pacific salmon appears to have produced a variant capable of completing its normal life and reproducing itself in fresh water."

In 1939, Dr. F. F. Fish, aquatic biologist, U. S. Fish and Wildlife Service, visited Crater Lake to investigate the infestation of the fungus, *Saprolegnia*, among the salmon in the lake. The four half grown fish, he collected at that time have been identified by us as kokanee and not silverside salmon as previously suggested, and this identification has been confirmed by Dr. Carl L. Hubbs. Two subadult salmon, also kokanee, were found dead on the surface of the lake in 1947.

These six specimens have the silvery, unspotted color, the body form, and the low, straight-edged anal fin characteristic of kokanees at their size. They agree also in the critical character of gill-raker number (Table 1). The range of variation of most taxonomic characteristics of *O. nerka kennerlyi* and *O. kisutch*, such as counts of scale rows and fin rays, overlap, but there is no overlap in the shape and number of gill rakers on the first gill arch. Silver salmon have few, short rakers, numbering 19–25, whereas kokanees have long, slender, numerous rakers, ranging in number from 30 to 39. The kokanee does not differ from the sea-going form of sockeye in these features, although the landlocked form is much the smaller, usually reaching a length of only 12 to 14 inches. The gill rakers in the six Crater Lake specimens vary from 30 to 35.

From photographs of catches made

TABLE 1.—TAXONOMIC CHARACTERS OF SILVER AND SOCKEYE SALMON COMPARED WITH THE COUNTS FOR CRATER LAKE KOKANEE

The counts for the species are taken from Clemens and Wilby (1946). Similar figures were given by Foerster and Pritchard (1935), with identical limits for gill rakers (125 counts for silver salmon and 317 counts for sockeyes).

Characters	Species		Crater Lake Specimens 1939				1947	
	Silver	Sockeye	#1	#2	#3	#4	#1	#2
Gill rakers	19–25	30–39	31	33	33	35	32	32
Anal rays	12–17	13–17	14	14	14	14	15	15
Scales in lateral line	121–136	125–139	135	126	132	129	133	128
Pyloric caeca	45–80	66–92	91	82	83	83	—	69
Spots	black spots numerous on back and upper lobe caudal fin.	no black spots	No black spots					

prior to 1947, we feel certain that silverside salmon have been present in Crater Lake, but the extent to which they reproduced in the lake is problematical. Sockeye salmon have not knowingly been reared at the hatchery from which the Crater Lake stock was said to have been secured. There is the remote possibility that the kokanees may have become mixed with silverside salmon at the egg-taking station, and once liberated into Crater Lake found the situation suitable and reproduced. Or, they may have been planted in the lake without authorization or record.

Because this dwarf form of sockeye salmon is more adapted to the environment of a landlocked lake such as Crater Lake than any other form of salmonoid fish, it is recommended that this species be given first consideration in future fish planting operations in Crater Lake. It apparently can and will reproduce in some landlocked situations without extensive spawning areas. This recommendation is in line with the National Park Service Fish Policy which prohibits the planting of an exotic species unless it has already established itself. The kokanee has established itself in Crater Lake.

SUMMARY

1. The kokanee (*Oncorhynchus nerka kennerlyi*) was found in Crater Lake, Oregon, in 1939 and 1947, although this species has not been recorded as having been planted in this landlocked lake.

2. Evidence is shown that this dwarf, landlocked form of sockeye salmon reproduces in Crater Lake.

3. It is recommended that this species be given consideration in future fish planting operations in the lake, as it is already present and appears to be better adapted than other species to the local conditions.

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STABILITY OF A STREAM FISH POPULATION[1,2]

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Investigations of fish populations have been concerned with two types of population statistics. First, any part of a lake or stream may be selected and its fish enumerated. The selected area is the most important consideration and its boundaries may be purely physical. A second type of fish population includes individuals of all ages, each age group being represented in its natural proportion. This might be termed the *natural* population, and it is preferable because its boundaries are biological and not physical. Natural populations of small lakes and ponds are not difficult to study because the physical and biological boundaries are identical. The study of natural stream populations is a different matter because the continuous nature of the stream environment allows fish free movement over hundreds of miles. Whether stream fish actually do move freely from one place to another is a question which must be answered before their natural populations can be determined. My observations indicate that certain stream species do not travel much during the summer and therefore do have stable populations during that time.

Over a period of years it might be expected that fish move rather great distances in streams. Thompson (1933) calculated migration constants for several stream species on the premise that they exhibit a random movement. On this basis the distance traveled is proportional to the square root of the time between tagging and recapture. This relationship is borne out by his carp

[1] Contribution No. 408 from the Department of Zoology, Indiana University.

[2] I wish to acknowledge the help and cooperation of William T. Miller, Richard Kizer and David Farris who participated in this study.

data but information about other species is scanty. For instance, he found 3 recoveries of 76 tagged rock bass, 0 recoveries of 10 tagged longear sunfish and 1 recovery of 5 tagged green sunfish, the 3 species which are here considered to have stable populations during the summer. He was considering a random movement of stream fish over a long period of time which would mask a temporary stay in one habitat, as he points out. I was interested in finding out how the fish behave during a single summer, excluding the breeding season.

If a fish population is stable, it must be able to withstand environmental stress without disrupting its composition. A flash flood is one of the most powerful stresses which stream fishes must combat, and it was fortunate that a population was studied before and after a flood. Any interpretation of the data should be strengthened by the occurrence of the flood because it is a natural and unpredictable phenomenon to which all stream fishes are subjected.

Richland Creek in Greene County, Indiana, meanders through limestone country where it has cut through the topsoil to the underlying bedrock. The water is always murky, although there is ample opportunity for suspended material to settle. Normal summer flow is hardly perceptible in the deeper parts of the stream. Secchi disc readings varied from 2 inches after a rain to 2½ feet when the creek was clearest. The creek is fed by springs so some flow of water is always maintained. The experimental area was 0.2 mile, consisting of 2 long pools separated by a 300 foot riffle. The riffle was 2 or 3 inches deep and the pools were about 3 feet deep. The width of the stream averaged about 30 feet.

The fish were captured by an electric fish shocker operating at an average of 150 volts and 2 amperes. Three men formed a team in the operations. Two men carried an electrode in one hand and a dip net in the other. The third man manipulated a 4 foot, ¼ inch mesh seine between the electrodes to catch fish which escaped the others. The middle man also dragged a floating live box strapped to his waist in which the captured fish were retained. The shocker was used because no other method catches fish of all sizes in rocky streams without killing them. Fish were taken from subsections about 60 feet long which were blocked off with ¼ inch mesh nets. The distance between the electrodes was less than the width of the stream, so the operators waded up and down between the blocking nets in a more or less regular fashion until the catch was negligible. This does not mean that the total population was caught, however. After the fish in one subsection were caught, marked and replaced, the operation was repeated in the next one. This sequence continued until the whole experimental area was covered.

The whole area was divided into 6 sections designated by the letters A through F, starting with the downstream section. Fish were marked differently in sections A, B, E and F (242, 184, 246, 117 feet long respectively) by removing one of the pectoral or ventral fins. Fish in section A were marked LP (left pectoral fin removed); section B fish were marked RP; fish in section E were marked LV (left ventral fin);

RV was the mark used in section F. Section C, a part of the long riffle, was worked intensively but the fish were not marked. Section D was never worked because the water was only 2 or 3 inches deep most of the summer. It was a real barrier to fish movement. The fish were marked progressively LP, RP, LV and RV in the same direction, LP in the extreme downstream section and RV in the extreme upstream section.

It was planned to reshock the area 2 weeks after the fish were marked, but

TABLE 1.—NUMBERS OF EACH SPECIES OF FISH MARKED IN A 0.2 MILE SECTION OF RICHLAND CREEK, GREENE COUNTY, INDIANA

Species	Section A Marked LP	Section B Marked RP	Section E Marked LV	Section F Marked RV	Total
Golden redhorse (*Moxostoma erythrurum*)	35	3	2	9	49
Hog sucker (*Hypentelium nigricans*)	6	13	5	4	28
White sucker (*Catostomus commersonii*)	3				3
Spotted sucker (*Minytrema melanops*)	3				3
Longear sunfish (*Lepomis megalotis*)	94	123	86	31	334
Green sunfish (*Lepomis cyanellus*)	2	2	10	3	17
Rock bass (*Ambloplites rupestris*)	22	21	25	8	76
Spotted bass (*Micropterus punctulatus*)	6	3	3	5	17
Smallmouth (*Micropterus dolomieu*)	5	3	2	3	13
Total	176	168	133	63	540

The other sections were separated by deeper water which probably did not hinder movement from one section to another. A total of 540 fish of 9 species were marked between June 18 and July 1 (Table 1). Longear sunfish made up 62 per cent (334) of the catch. Rock bass were next most numerous and the other species were caught in smaller numbers.

It is important to keep the geographical sequence in mind for the following discussion. The sections are lettered consecutively from A to F, starting at the downstream end of the area and progressing toward the upstream end.

rain fell on 11 of 12 days beginning July 12, disrupting the schedule. A total of 6.60 inches of rain fell during this time (recorded at Bloomington, Indiana, the nearest weather station). The stream changed from a quiet, placid creek to a raging, destructive torrent which flooded its banks and poured onto farm land. No distinction could be made between riffles and pools. The creek was a mass of swirling, dirty water. The peak of the flood was 5 feet $11\frac{3}{4}$ inches above a water level marker established a short time before. During the flood the water in the deepest part of the stream was 9 feet deep

rather than its customary 3 feet. The volume of water was, of course, much more than 3 times the normal amount. Just before the peak of the flood on July 20, a Secchi disc could be seen only 2 inches below the surface of the one exception. A stop-net was placed in the creek overnight at the point where operations ceased, to prevent the marked fish which had been caught and released on that day from mixing with the other marked fish in the stream.

TABLE 2.—NUMBERS OF FISH OF EACH SPECIES RECAPTURED AFTER THE FLASH FLOOD*

Species	Recaptures in Section A, Where All Had Been Marked LP				Recaptures in Section B, Where All Had Been Marked RP			
	LP	RP	LV	RV	LP	RP	LV	RV
Golden redhorse	3	1			2			
Hog sucker	1					1		
Spotted sucker	2				1			
Longear sunfish	9	4			3	17		
Green sunfish						1		
Rock bass	3					1		
Spotted bass	5	1				1		
Smallmouth bass	1	1			2			
Total	24	7			8	21		
	Recaptures in Section E. Where All Had Been Marked LV				Recaptures in Section F, Where All Had Been Marked RV			
Golden redhorse	1		1	2	1		1	
Hog sucker				1				1
Spotted sucker								
Longear sunfish		1	30	1			2	9
Green sunfish			4				1	1
Rock bass			9				1	
Spotted bass		1	1	1				
Smallmouth bass	1						1	1
Total	2	2	45	5	1		6	12

* 2 hog suckers marked RP, 1 hog sucker marked RV and 1 longear sunfish marked RP were recaptured in section C. No white suckers were recaptured so they are not included in the table.

water. The disc disappeared 4¼ inches beneath the surface 3 days after the flood peak. It subsided and the work was to be resumed on July 28, but 1.37 inches of rain fell on that day and postponed operations a second time. This rain caused no flood, but the water rose considerably and became very muddy. The Secchi disc disappeared 3¾ inches below the water surface on July 29. Finally, shocking operations were resumed on August 2. The procedure used was the same as described above with

The numbers of marked fish caught after the flood are shown in Table 2. It is remarkable that 75 per cent of the fish were found in their original location. In section A where all the fish had been marked LP, 24 of 31 fish bore this mark. There was a movement of 7 fish downstream from section B where they had been marked RP. Section B yielded 29 marked fish of which 21 had remained in the same area where they were marked. Eight fish had moved upstream from section A below. Half

the mixing between sections A and B had taken place in adjacent subsections. No fish had moved downstream over the long riffle into sections A or B. Longear sunfish made up most of the catch as they had previously and showed a strong tendency to remain in the place where they had been marked. Smallmouth bass moved more than any other species; 3 of the 4 recaptured bass were caught in "foreign" territory.

A hog sucker marked RV was found in section C which is located in the long riffle. This was the only fish which had moved downstream through the riffle area.

A somewhat different situation was found above the long riffle. All 4 kinds of marks were found among fish caught in section E where the LV mark was originally used. Even here, however, 45 of 54 marked fish bore the LV mark. Five fish marked RV in section F had moved downstream. A redhorse (found dead) and a smallmouth bass, both from section A, and a longear sunfish and spotted bass from section B had traveled upstream across the long riffle. Of 19 marked fish caught in section F, 12 bore the RV mark of that area. Six fish had wandered upstream from section E and 1 redhorse came from section A. The great majority of fish were found in the same place where they had been marked before the flood.

It is hardly fair to consider all species as one group. This has been done, however, to illustrate the fact that the flood had very little effect on the population as a whole. Enough marked longear sunfish were caught to conclude that the great majority definitely live in confined areas. Of a total of 77 recaptured longears only 12 had moved to areas other than where they were marked. Seven had moved upstream and 5 had moved downstream. Although not represented in as large numbers, green sunfish showed the same behavior. Rock bass were also "stay-at-homes." One of 14 recaptured fish was found a short distance upstream from the area where it was marked. This strengthens and confirms the work of Scott (1949) who has made some extremely pertinent observations about the homes of rock bass in the Tippecanoe River, Indiana. He states, "It is at once apparent that fish marked at one location showed a strong tendency to remain there. This tendency was still present even after as long as 2 years. It is equally apparent that there was a certain amount of moving about of marked fish, both upstream and down, and seemingly about the same in either direction." Other warm water stream fish have been studied by Bangham and Bennington (1938) in this connection. They tagged native fish in 3 Ohio stream sections, each 1 mile long. Their observations include these remarks: "At each of the stations more recaptures came within 2 weeks after the fish were tagged than in later seining trips, but a few fish tagged early in the season were recovered late in the summer in the same mile of stream. . . . No marked fish were taken by us except near the station where the tagging was done." Some of their fish obviously stayed home all summer.

Among cold-water species, the brown trout exhibit a tendency to stay home over considerable periods of time according to Shuck (1943) in Crystal Creek, New York. It is worth repeating a few of his statements. "Of 46 fish re-

covered in the annual September inventories after being tagged for a period of 1 year, 42 were taken in the identical individual sections in which they were tagged the previous September. This appears remarkable considering the fact that these sections had an average length of only 214 feet, and that a year had passed since tagging in those sections. The remaining 4 fish were taken from 400 to 1,300 feet from the point of tagging—2 upstream and 2 downstream. . . . In addition there were 5 fish that were taken in the identical inventory sections 3 years in succession."

Shuck also operated a weir upstream from his experimental section and found that the trout moved several miles upstream to spawn and later returned to the identical section where they were tagged. He was evidently dealing with a stable brown trout population over a considerable period of time. Even his information is not sufficient to close the question on brown trout since there may be geographical variations in their habits. Shetter (1937) found some stability among brook trout in a branch of the Au Sable River in Michigan. From 50 to 100 per cent of the fish showed no migration from the point of tagging from June to early September. His evidence also led to the conclusion that the trout moved downstream over winter, and the next spring at least one-third returned to the place where they had been tagged while the other two-thirds returned to less than a mile up or downstream from the point of tagging. Variations in his data are great enough to demand that stability of brook trout populations must be considered. Shetter and Hazzard (1939) discovered that populations of brook, brown and rainbow trout were not stable in stream sections about 100 feet long during one summer. Hunstman (1948) mentions, "Both salmon and trout, as is well known, may become related to particular local environments which may become their homes," but he gives no data to support this statement.

Smallmouth bass were the greatest roamers in Richland Creek: 5 of 7 recaptured fish were found in "foreign" territory. The spotted bass did not travel as much as the smallmouth but larger numbers of both species would have to be studied for any positive judgement. The suckers moved around quite a bit but they again are represented by small numbers. It might well be said that if it were not for the smaller centrarchid species the results would show that fish tended to move more or less at random. However, remember that relatively short distances are involved in the movement of the individual fish. It is remarkable that the flood had so little effect on their movement.

Of course, nothing is known concerning the whereabouts of those marked fish that were not recaptured. It is assumed that the movement of the recaptured fish represents a true sample of the whole number that were marked. Some light on the validity of this assumption was obtained by shocking extensive areas downstream from the experimental area where not a single marked fish was caught. There was one deep pool in this downstream area which could not be worked and might have contained marked fish.

Table 3 discloses that 102 of the recaptured fish were found in their origi-

nal location, while 35 had moved to some other area. Of these 35, 22 had moved upstream and 13 had moved downstream from where they were first found. A tendency to move upstream during the flood is suggested, but the hypothesis of an equal movement in both directions is not disproved ($\chi^2 = 1.83$ with 1 degree of freedom). The fact that 5 fish moved upstream through the long riffle while only 1 moved downstream over it during the high water adds strength to this interpretation.

TABLE 3.—MOVEMENT OF FISH IN RICHLAND CREEK AS DETERMINED BY THE CAPTURE OF MARKED FISH AFTER A FLASH FLOOD

Species	Fish Remaining Where They Had Been Marked	Upstream Movement		Downstream Movement	
		Number	Average Distance Ffeet	Average	Average Distance Feet
Golden redhorse	4	5	432	2	133
Hog sucker	3	2	117	3	300
Spotted sucker	2	1	251		
Longear sunfish	65	7	200	5	150
Green sunfish	6	1	217		
Rock bass	13	1	217		
Spotted bass	7	1	484	2	154
Smallmouth bass	2	4	334	1	117
Total	102	22		13	

The distance that each fish had moved was measured from the midpoint in the section where it was marked to the midpoint in the subsection where it was recaptured. Distances that fish moved downstream are compared with those that moved upstream in table 3. Fish moved upstream an average of 110 feet farther than they moved downstream. The probability that this result could have occurred by chance is .08 ($t = 1.79$) by Fisher's test, slightly below the usually accepted limit of statistical significance. Again the tendency of the Richland Creek fish to move upstream during the high water is strongly indicated. Movements of the golden redhorse and smallmouth bass contributed mainly to the average difference between the downstream and upstream movement. These two species contributed 54 per cent of the total distance traveled upstream and only 17 per cent of the distance traveled downstream. Yet these fish are not represented by enough individuals to justify a general conclusion that they move from one place to another more freely than other species or that their general movement is upstream. The general impression is that the flash flood stimulated fish to move upstream rather than being forced to lose ground.

The possibility remains that the flood may have affected large and small fish differently. Since small fish are not as strong as large ones, they may have been washed downstream while the large ones remained. The data would then be biased, as far as the whole population is concerned, in favor of the large fish. Figure 1 gives the length frequency distribution of longear sunfish marked before the flood and those

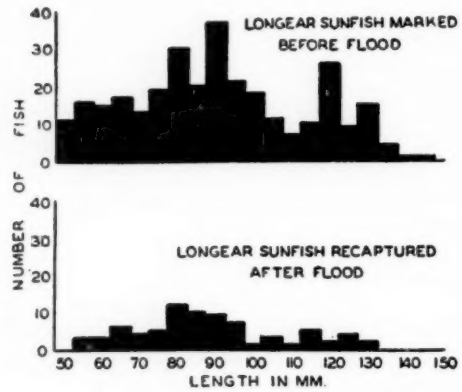

FIG. 1. Length frequency distributions of longear sunfish marked before and recaptured after a flash flood in a 0.2 mile section of Richland Creek, Greene Co., Indiana.

that were recaptured after the flood. The two length frequencies have practically the same shape and the mode occurs in nearly the same place. The range of sizes among the recaptured fish is somewhat smaller because fish at each end of the distribution were not caught, but this is the usual case of any sample taken from a larger group. The two frequencies were tested by the chi-square method to find whether the difference between them could be due to sampling variation or whether the samples were from different populations. The chi-square value was 15.5, far below the significant level (13 degrees of freedom). The difference may thus be due to sampling variation. The same characteristic difference in frequency distributions held for all other species which were taken in quantity. The size range of the original rock bass group was 50 to 230 mm. (av. 95 mm.) and the recaptures varied from 60 to 165 mm. (av. 124 mm.). Golden redhorse ranged from 165 to 300 mm. in length (av. 213 mm.) and their recaptures from 168 to 280 mm. (av. 227 mm.). Therefore, it is safe to conclude that small and large fish were equally affected by the flood.

It is difficult to realize how fish, especially small ones, are able to escape the force of the current for a sufficient length of time to prevent being swept away, but all the information leads to the conclusion that this is exactly what happens. Due to friction the current is not as swift near the bottom and bank as it is at the surface in midstream. Quieter water is also found behind stones and other obstructions. The interesting point is that fish seek such shelter in times of environmental stress. The damage to agricultural crops is certainly no measure of the effect of a flood on a fish population. Apparently they take it in stride, much as we do a short, violent windstorm.

The experimental area was spot-checked on August 26 and 27 by shocking four subsections a second time after the flood. This served to check the accuracy of the first observations and also to discover any movement which had taken place since the last shocking. The number of marked fish recovered is found in table 4. Of the 47 recaptured fish 33 or 70 per cent of them were found in their original location. These fish had remained within 100–200 feet of their original location since mid-June. As shown by the first shocking after the flood, 75 per cent of the fish had remained in their homes. A small amount of movement had evidently occurred since that time. These data are not strictly comparable since the same marked fish may have been caught both times. Some fish may have been

caught away from home the first time and later traveled back home where they were caught the second time. However, both data agree closely as to the amount of movement which had taken place from mid-June to September.

Critical examination of the experiment brings out two important points which must be cleared up before the "home area" hypothesis can be accepted without qualification. The electric shock may affect the fish in such a way that they do not behave naturally. The shocked fish may be less active than unshocked fish or the shocking may stimulate fish to greater movement. This is a very definite possibility and must be investigated. Marking the fish may also influence their movement from one area to another although Ricker (1949) has shown that marking imposes no additional mortality among large spiny-rayed fishes. Finally, the fish were observed only during the summer months and the observations do not necessarily apply to winter and spring. It is well known that during high water in the spring fish are found stranded outside normal stream boundaries. Spring is the time when mating occurs and the fish are competing for suitable spawning areas. This may encourage them to seek places which they would not normally inhabit. The experiment reported here was performed after the main breeding season and there was no prolonged flood.

Information about stability of fish populations of other streams is scarce but encouraging. There does seem to be population stability among brown trout (Shuck, 1943), brook trout (Shetter, 1937) and rock bass (Scott, 1949). The longear sunfish and green sunfish may be added to this list on the basis of the information presented here. The population stability of these stream species must be reaffirmed and others investigated before final conclusions can be reached.

TABLE 4.—NUMBERS OF MARKED FISH RECAPTURED UPON SHOCKING 4 SUBSECTIONS OF THE STREAM A SECOND TIME AFTER THE FLOOD

Species	Fish Remaining Where They Had Been Marked	Upstream Movement	Downstream Movement
Golden redhorse	3	1	
Hog sucker	4	1	1
Spotted sucker			
Longear sunfish	16	2	
Green sunfish	2		
Rock bass	5		
Spotted bass	1		1
Smallmouth bass	2	6	2
Total	33	10	4

SUMMARY

1. A stream fish population was studied to gain information regarding its stability during the summer months. During the observations a flash flood occurred which allowed an evaluation of the effects of a natural physical stress on the population.

2. Fish of 9 species were marked dif-

ferently in different parts of the stream before the flood. After the flood waters subsided, 75 per cent of the total number of recaptured fish were found in their original location. Two weeks later 70 per cent of the fish were living in the same place where they were originally marked. Length frequency distributions of the fish marked before and recaptured after the flood were substantially the same. Evidently the small fish were affected no more than the large fish. There was a general tendency for fish to move upstream during the period of high water.

3. The interpretation placed on the data is that individuals of certain species occupy "homes" during the summer months. That longear sunfish have "homes" is definitely indicated by the information presented. Green sunfish and rock bass also follow the same pattern. The spotted and smallmouth basses and 3 sucker species moved around more than the smaller centrarchids but the distances covered by these fish were not great. They were represented by too few numbers to draw any positive conclusions.

4. Criticisms that shocking and marking may affect fish movement must be answered before the "home area" hypothesis among stream fishes can be accepted without qualification, but these and other experiments point to the fact that certain fish species do have "homes" during the summer months and that their populations are therefore stable during this time.

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THE USE OF ROTENONE TO REMOVE ROUGH FISH FOR THE PURPOSE OF IMPROVING MIGRATORY WATERFOWL REFUGE AREAS

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Introduction

Along the shores of Sandusky Bay in Ohio some shallow lakes and marshlands were developed into excellent refuge areas for migratory waterfowl. In Middle Harbor, a marsh which had provided a resting place for thousands of wild ducks during the fall, a large population of carp developed. The value as a waterfowl refuge decreased steadily as the population of carp increased. Therefore, it seemed that if the carp could be removed that the aquatic vegetation which originally existed in the marsh would again flourish, and the food for wild ducks would again become abundant. This theory was tested in a small way in a small marsh covering about one half acre, using rotenone in a manner somewhat like that described by Siegler and Pillsbury (J. Wildl. Mgt., **10:** 308–316, 1946). Within two weeks an excellent bloom of algae had developed and the water became clear. Since the area of Middle Harbor was 250 acres, the problem of application was difficult. A helicopter was used to apply the rotenone on October 6, 1948 and proved to be ideal for this purpose. This is believed to be the first use of a helicopter to apply rotenone emulsion for fish control.

Method of Application

The Bell helicopter was equipped with dual tanks for insecticides with a 10½ foot boom on either side of the plane. The rotenone mixture was sprayed from 6 holes, one half inch in diameter, evenly distributed along the entire length of the two booms. No nozzles were required because the speed of the flight broke up the streams of liquid into fine droplets before they struck the water. The total width of the two booms was about 25 feet and flying at a speed of 70 miles per hour, 6 to 10 feet off the water, a strip of about 40 feet was covered with the spray.

The Emulsifiable Rotenone 5% was diluted with 2 to 3 volumes of water, which means that the concentration of rotenone in the finished emulsion was 1.3% to 1.7%. A maximum of 30 gallons of emulsion could be carried at each load and the load was dumped in about one minute. Applying the emulsion in strips of 40 feet and leaving a distance of about 40 feet between strips, the entire lake of 250 acres was covered with 22 loads. The operating time for the 250 acres was 2½ hours, which means that about 7 minutes was required for filling the tanks and applying each load.

The lake was shallow, averaging only

about 4 feet in depth, and a total of 170 gallons of Emulsifiable Rotenone 5% was applied. About 10 gallons of the Emulsifiable Rotenone diluted with 6 to 8 volumes of water were applied along the weedy areas at the shore line, using Indian fire pumps operated from boats. The dosage was calculated on the basis of 0.5 parts of Emulsifiable Rotenone 5% per million parts of water. This amounts to 1.36 pounds per acre-foot or about one gallon of Emulsifiable Rotenone 5% for each 6 acre-feet of water.

RESULTS

The water temperature was 52°F. and the first fish was observed on its side 38 minutes after the first application of rotenone. Four hours after the start of the application, fish were turning up in all parts of the lake. The following day fish were collected from the banks of the lake by the hundreds. Many fish were still alive but were severely affected. Five days after the application, there was no evidence of any living fish in the lake.

Over a period of several days following the actual treatment, there were winds from all quarters which in turn washed or piled up the water first in one section and then in another, with the result that all shores, the cat-tails, the rushes, the little isolated spots, all got a good bathing. We found dead fish in the muskrat holes and in other spots it would have been practically impossible to reach either by air or from the boat.

About 95% of the fish collected were carp. In addition to carp, there were also shad, bluegills, perch, crappies, bullhead, bass, goldfish, minnows, pike and common sunfish. The largest fish observed was a carp 35 inches long and there was a good distribution of all sizes up to 35 inches.

Six or seven tons of fish were buried in furrows and estimating as best we can, the dead fish that came up for days and drifted to the banks, plus the quantity consumed by about two thousand gulls frequenting the harbor for weeks, we believe we are quite conservative when we say that upward of fifteen tons were the result of the operation. The gulls (herring, ring-billed, and Bonaparte's) ate the dying fish, until they were hardly able to fly, without any apparent harm from the small amount of rotenone consumed. A few of the large-mouth black bass and bluegill sunfish were fried and eaten by some of the men to determine that there was no off-taste due to the rotenone emulsion.

It has been amazing to see the change in the water. Within three or four days, in isolated spots the water began to clear and within two weeks, it was possible to see bottom clearly in three feet of water.

For several seasons, we have noted how uneasy waterfowl were after alighting in the lake and it was interesting to see how wary and apparently frightened these birds were as was shown by their actions. Within a few moments after alighting, the birds would become uneasy, rise off the water and alight again a few hundred feet away, and this would be repeated until finally they would leave. This fall, with the fish gone, it was most interesting to note the behavior of the birds and many people witnessed and commented on the difference. Birds by the hundreds

and at times by the thousands alighted in Middle Harbor and rested in perfect contentment for hours at a stretch not leaving the harbor when they took wing, alighting only at another part.

It is now obvious that the physical presence of the fish was disturbing to the waterfowl that used Middle Harbor as a refuge. The fish may have been attracted to the spot where the birds came to rest, and the approach of the fish could have caused the birds to move from place to place. The removal of the carp was therefore, considered to be a successful step in the improvement of the area for waterfowl, even though it is too early to give a complete report on the effect on aquatic vegetation.

(Supplemental Note: Observations made seven and a half to nine months after the treatment indicated that a few fish were present in the lake. A school of about 100 one-inch-long silvery minnows, two gars about two feet long, four carp eight to twelve inches long and one goldfish about eight inches long were seen. Earlier it had seemed that a complete eradication of all fish had been obtained but now it must be presumed that some of the above mentioned fish survived the treatment, even though neighboring fish-infested waters reach to within fifteen to twenty feet of treated lake.)

SUMMARY

An application of Emulsifiable Rotenone 5% at the rate of one gallon for 6 acre-feet of water, using a helicopter to cover a 250 acre lake, averaging 4 feet in depth, gave what appeared to be a complete kill of carp and at least ten other species of fish. The dosage was 0.5 parts per million of 5% rotenone. With the water temperature at 52°F., the first fish was observed on its side in 38 minutes. Many fish were alive but badly affected 24 hours after the treatment, but observation at 5 days failed to reveal evidence of any living fish. An estimated total of 15 tons fish were killed in the lake.

Observation of migratory waterfowl on the lake before and after the eradication of the carp indicated that the fish frightened the birds until they finally left the lake. The elimination of the carp has improved the lake as a refuge for waterfowl.

ACKNOWLEDGEMENTS

The opportunity to observe the airplane application of rotenone emulsion to lakes in New Hampshire, through the kindness of the State Fish and Game Commission, provided helpful experience which enabled us to speed up the operation by removing the insecticide spray nozzles and deliver the emulsion through one-half inch holes.

The pilot of the helicopter was Mr. Bruce Jones of Indianapolis, Indiana.

The operation was conducted with permission of the Department of Public Health and the Fish and Game Commission of the State of Ohio.

We wish to acknowledge the help of John Anderson who will report on the development of the aquatic plants after his observations are completed at the end of the 1949 season.

SOME AQUATIC VEGETATION CHANGES FOLLOWING FISH REMOVAL

John M. Anderson

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The preceding paper by Weier and Starr describes the removal of fish from Middle Harbor. The present paper concerns the history of the lake prior to the application of rotenone, and a comparison of the vegetation in the growing seasons immediately prior to, and following the treatment.

The area described is located on the northeast side of Marblehead Peninsula which is a part of Ottawa County, Ohio, extending into southwestern Lake Erie. Middle Harbor covers about 250 acres.

Prior to construction of a causeway, Middle Harbor was a continuation of East Harbor. Originally, the two water areas appear to have been an embayment, but a gravel bar formed across the open end, until only a narrow channel connected the water of Lake Erie with the so-called harbor area.

According to the natives of Port Clinton, Ohio, Middle Harbor and East Harbor had long been famous for largemouth bass fishing and canvasback shooting. Prior to 1945, according to Mr. Weier, owner of Middle Harbor, there were vigorous growths of such aquatics as wild celery (*Vallisneria americana*), sago pondweed (*Potamogeton pectinatus*), milfoil (*Myriophyllum exalbescens*), and emergents such as soft-stem bulrush (*Scirpus validus*) in his lake. Before construction of the causeway, fish from Lake Erie could enter and leave at will, via East Harbor. Although carp and other species were permitted to spawn, the water remained clear and the vegetation was apparently unaffected.

In the spring of 1945, at the height of the spawning season, construction of the causeway made Middle Harbor a land-locked lake, enclosing the entire breeding population of fish. Three years later, in 1948, when a cursory inspection of Middle Harbor was made by the writer, conditions had vastly changed. In quiet water, a 10-centimeter Secchi disc disappeared at a depth of 10 inches. With a 15 m.p.h. breeze, the disc was not visible at four inches. The average depth of the lake was about four feet, six inches. In mid-September of 1948, the bottom of the lake was dragged from one end to the other several times with an ordinary garden rake, but only an occasional specimen of sago pondweed, curly-leaf pondweed (*Potamogeton crispus*), or water milfoil could be recovered by this method. The excessive carp population was visible everywhere about the lake. Only six largemouth bass, plus a few bluegills and crappies, were reported caught by anglers in 1948.

After surveying the lake, the writer was asked by Mr. Weier for management recommendations, whereupon the removal of the fish by use of rotenone was suggested. The application of the rotenone, using a helicopter, on October 6, 1948, and the removal of the fish are described in the accompanying paper. Periodic checks on the vegetation were made by the writer throughout the

1949 growing season, and in mid-September, a semi-quantitative survey was undertaken.

A wire hoop, two feet in diameter, was dropped over the side of a rowboat at 50-foot intervals. The boat was rowed in a straight line across the lake several times from east to west, then from north to south. The clarity of the water permitted a count of the number and species of plants within the circle.

The greatest depth found was four feet, two inches, at which depth, the Secchi disc was plainly visible. The average depth was about six inches less than in 1948. The total alkalinity, taken in August, was 77.6 parts per million. Although the water is definitely alkaline in reaction, total alkalinity readings are as high, or higher, in Lake Erie and other local waters. Total alkalinity data for 1948 are, unfortunately, not available. The lake has a very soft, easily-roiled bottom. The most obvious change is, of course, the clarity of water following removal of the fish population.

The following discussion is based upon the relative abundance of 18 species of aquatic plants in the two years under comparison. Five of these species comprised at least 95% of the lake bottom cover in 1949. The term "Frequency of Occurrence" indicates the per cent of the total samples in which each plant occurred.

Chara vulgaris, Muskgrass

1948—Not found.

1949—Frequency of occurrence: 95%.

The growth of this alga has been remarkable. By early May, the plant had formed a dense mat, covering practically the entire bottom of the lake. The density of the stand varied inversely with the depth of water, but even in the deepest areas (4′2″) an average of two plants per square foot was found. This lush growth may have retarded other species to some extent. Occasionally, however, young *Vallisneria* shoots were noted growing up through the *Chara*.

Potamogeton pectinatus, Sago Pondweed

1948—Very rare; rarely recovered by raking the bottom.

1949—Frequency of occurrence: 28%.

The spread of this species has been substantial, but moderate when compared to that of *Chara*. Seed production in the clear water appears to be stimulated and prolonged throughout the early fall, whereas, in nearby turbid waters, the reproductive phase is limited to May and June. Should this prove to be a lasting effect of decreased turbidity, the increased supply and availability of seed will be of distinct benefit to waterfowl.

Vallisneria americana, Wild Celery

1948—Not found.

1949—About 6,000 *Vallisneria* tubers were planted on April 24, 1949. The ultimate effect of this planting is difficult to measure since comparable growth has been noted in some areas where the tubers were not sown. Therefore, although it appears that the planting was successful, it is suspected that the natural reproduction would have eventually brought on the same results, although probably not as rapidly. Growth of the plants has been relatively slow. In late June, when first noticed, the average wild celery leaf was about 2–3 inches long. By mid-September, the

average length of leaf was not more than 12–14 inches, the tips well below the surface, compared to floating leaves several feet long in nearby Lake Erie. Seed production was very rare, and occurred only in water less than 14 inches deep.

Myriophyllum exalbescens, Water Milfoil

1948—The dominant submerged aquatic, although scattered beds probably did not exceed 10 acres combined.

1949—Frequency of occurrence: 5%.

There appears to be very little change in the abundance of this species compared to last year. In adjacent East Harbor, which is separated from Middle Harbor only by a causeway, *Myriophyllum* practically excludes all other species, growing in such profusion as to make boat passage difficult. In view of its abundance in East Harbor, *Myriophyllum* may be expected eventually to replace much of the present stand of *Chara*.

Najas marina, Bushy Pondweed

1948—Not found.

1949—Frequency of occurrence: 2%.

It is interesting that *Najas marina*, which is rare throughout the region, should be fairly common, while the widespread *N. flexilis* is quite rare in the present flora of the lake.

Potamogeton crispus, Curly-leaf Pondweed

1948—Co-dominant with *Myriophyllum;* total acreage roughly 10 acres.

1949—Frequency of occurrence: 0.1%.

No significant change in abundance has occurred. By July the plant appeared to become dormant, sink below the surface, and the vegetative parts disintegrated. This mid-summer disappearance is rather common in local waters. The species is thus more abundant than the frequency of occurrence in mid-September would indicate.

FLOATING LEAVED AND EMERGENT SPECIES

The white water lily, *Nymphaea tuberosa*, covered about one acre in 1948, and little change was noted in 1949.

American lotus (*Nelumbo lutea*) occupied about ten acres in a cove on the west side of the lake during both years.

Yellow water lily (*Nuphar advena*) did not cover more than one quarter-acre during either year.

Growth of soft-stem bulrush (*Scirpus validus*) is very sparse. Widely scattered individual plants occur over most of the lake. Change in density was not apparent following removal of the fish.

Pickerelweed (*Pontederia cordata*) occurs sparingly in scattered beds, covering about one acre combined. No change in abundance was noted.

The following species were present in 1949, but were so rare that they did not occur in any of the bottom samples:

Najas flexilis, Naiad

Potamogeton foliosus, Leafy pondweed

Potamogeton natans, Floating pondweed

Potamogeton pusillus, Small pondweed

Potamogeton richardsonii, Richardson's pondweed

Potamogeton zosteriformis, Flat-stemmed pondweed

Zannichellia palustris, Horned pondweed

No concerted effort was made to discover all the species present. A more intensive study will no doubt add many species to the above list.

SUMMARY

A semi-quantitative survey of aquatic vegetation of Middle Harbor was made in the growing seasons immediately prior to and following the removal of the fish population. The spread of *Chara vulgaris* over almost the entire lake bottom was by far the greatest change in abundance of any plant species. *Potamogeton pectinatus* and *Vallisneria americana* likewise made significant increases in abundance, while *Myriophyllum exalbescens* and *Potamogeton crispus* remained about the same in both years. The floating leaved and emergent species showed no significant changes in abundance following fish removal.

SOME OBSERVATIONS ON SEX RATIO OF DUCKS CONTRACTING BOTULISM IN NORTH DAKOTA

M. C. Hammond

Fish and Wildlife Service, Lower Souris Refuge, Upham, N. D.

The fact that North American waterfowl populations contain an excess of males is well established. Botulism losses have been suggested as one of the factors operating to bring about this condition.

Although great numbers of sick and dead ducks have been removed as sanitation measures from infected North Dakota marshes, the sex or age was, unfortunately, rarely recorded. The Fish and Wildlife Service does have data on 9,112 birds obtained between 1937 and 1947 at four National Wildlife Refuges in the State.

The information from Des Lacs (2,986 birds) and Upper Souris (1,526 birds) was of banded ducks released from the hospital pens between 1937 and 1946. The field pickup record kept by the writer while at Long Lake Refuge in 1942 included 4,530 ducks with sex and age data. A few field notes from Lower Souris in 1946 and 1947 included sex information (70 birds).

Adult totals for September undoubtedly include some birds of the year, since plumage characters were used in determining age. After the last of August the juvenile tail of pintails and mallards is replaced and its absence is not a reliable age character for adults. The sex ratios probably contain only insignificant inaccuracies, if any. In the few instances where it appeared that the banding operator lacked experience in determining sex, the records were not used.

The possiblity that, for physiological reasons, females might be more susceptible to sickness than males was not overlooked. This could introduce a serious error into the sex ratios from

Des Lacs and Upper Souris, since recoveries would be higher with male birds and a disproportionate number would be banded. Records from the Long Lake duck hospital (1942) show about the same recovery rate for females as for males, however, 66 per cent of 286 females and 61 per cent of 512 males. (Of 176 immature birds treated only 38 per cent recovered.)

Des Lacs (Kenmare, N. Dak.). Sickness was found principally in Upper Des Lacs lake, which, during the period of greatest loss, was shallow and bordered by extensive mud flats. The area was not especially attractive to male birds during the summer, and this may account for that refuge having a higher proportion of females contracting botulism than the others.

Upper Souris (Foxholm, N. Dak.). Losses were mainly limited to newly flooded upland weed beds and some stands of emergent marsh vegetation. Moderate numbers of male birds move into these habitats during the summer. Sick female pintals, shovellers, blue-winged teal and baldpates were recorded in about equal or greater numbers than males.

Long Lake (Moffit, N. Dak.). At the water levels prevalent in 1942 there was an extensive prairie bulrush (*Scirpus paludosus*) and hardstem bulrush (*Scirpus acutus*) marsh which made the refuge an important male gathering area that year. Males greatly exceeded females in all species but redhead in the botulism pickup record.

Lower Souris (Upham, N. Dak.). The summer influx has frequently exceeded 100,000 male ducks. This has undoubtedly resulted in a higher proportion of males contracting botulism. The first recorded outbreak on this refuge was in 1945.

Each of these refuges has been, to a varying degree, an important gathering area. Not only was there an influx of males, but also to a lesser degree of females and young from surrounding potholes and sloughs.

We have some information which will indicate the extent to which male birds move into favored marshes and the summer sex differential in populations there.

Waterfowl population counts were made on sample margins of marshes or open water bodies during April, May and June, 1948 at several North Dakota refuges. The writer has selected certain inventories made between May 20 and May 28 as most nearly approaching the resident population. Counts between June 17 and June 23 include local birds plus influx, which was just getting well under way by that time.

The combined count of four Lower Souris samples having 7.3 miles of shoreline bordering marsh areas was 492 ducks on May 20–21 and approximately 2,000 on June 18–21. Male mallards increased from 6 to about 1,000, male baldpates from 6 to about 80, male pintails from 49 to about 100. The remaining increase was distributed among males of gadwall, shoveller, blue-winged teal, black and the diving species. Female baldpates, pintails and bluewings likewise showed substantial increases during the period, but part of this may have been due to local nest failures, after which the hens would have been seen again on water areas.

Upper Souris counts on 7.9 miles of shoreline along the open water portions

of Lake Darling increased from 212 on May 24 to 385 on June 17. The increase in mallards was: males, 21 to 171; females, 9 to 33. Gadwall males increased slightly, a flock of male scaup (36) and a few new redheads and canvasbacks had appeared the latter date, while both sexes of other species declined. The males evidently moved to other areas later in the season prior to loss of flight feathers.

At Des Lacs there was an increase in mallards and male scaup, but a decrease with all other species between May 28 and June 23. Our counts there were also limited mostly to open water areas.

As a result of greatly increased water levels much of the latter two refuges is no longer as disproportionately attractive to male birds as it was during the earlier years when botulism outbreaks took a large toll of ducks.

Between July 9 and August 21, 1948 corral type traps were used at Lower Souris to capture flightless birds for banding. These traps were set in marsh environments which had in some years been responsible for botulism losses. No bait was employed and the sample should have been representative of the sexes of the adult flapper congregations. The proportion of females increased as the summer advanced, due to the fact that the average period of moult is later than for males.

Mud flats and bars were used as loafing areas by great numbers of males both prior to and again after the loss of primaries. When these were near extensive stands of emergent vegetation harboring flightless birds they also had continuous heavy use. Since the edge of these bars and flats is frequently a source of toxin at a location where it is apt to be ingested while birds are feeding, the losses there ran strongly to males as long as males were preponderant in the population.

TABLE 1.—DUCKS TAKEN IN CORRAL TRAPS, JULY 9 TO AUGUST 21, 1948. LOWER SOURIS REFUGE

Species	Females	Males
Mallard	0	96
Black	0	3
Gadwall	3	53
Baldpate	7	168
Pintail	45	222
Green-winged Teal	2	15
Blue-winged Teal	2	13
Shoveller	1	1
Total	60	571

TABLE 2.—IDENTIFIED BOTULISM LOSSES AT LOWER SOURIS REFUGE, SEPTEMBER 3 TO 17, 1948

Species	Adult		Immature	
	Female	Male	Female	Male
Mallard	27	39	12	22
Gadwall	7	1	3	2
Baldpate	15	6		
Pintail	35	9	2	3
Green-winged Teal	8	17	2	1
Blue-winged Teal	5	13	8	3
Shoveller	2			
Total	99	85	27	31

TABLE 3.—AGE AND SEX DISTRIBUTION OF BOTULISM-AFFLICTED DUCKS FOR EACH REFUGE, 1937–1947

Species		Adult Female	Adult Male	Ad. M per 100 Ad. F	Immature Female	Immature Male	Unidentified Immature
Pintail	Des Lacs	638	456		74	54	41
	Upper Souris	415	392		2	1	2
	Lower Souris	9	21				
	Long Lake	693	1,461				89
	Total	1,755	2,330	133	76	55	132
Mallard	Des Lacs	121	165		18	22	5
	Upper Souris	131	378		3	1	1
	Lower Souris	3	8				
	Long Lake	259	573				25
	Total	514	1,124	219	21	23	31
Shoveller	Des Lacs	154	150		8	11	11
	Upper Souris	18	16			4	
	Lower Souris		1				
	Long Lake	141	355				174
	Total	313	522	167	8	15	185
Green-winged teal	Des Lacs	113	173		17	17	3
	Lower Souris	1	25				
	Long Lake	79	284				11
	Total	193	482	250	17	17	14
Blue-winged teal	Des Lacs	140	234		7	11	3
	Upper Souris	19	18				
	Lower Souris	1	1				
	Long Lake	82	171				30
	Total	242	424	175	7	11	33
Gadwall	Des Lacs	102	96		4	16	18
	Upper Souris	38	58				2
	Long Lake	7	15				10
	Total	147	169	115	4	16	30
Baldpate	Des Lacs	18	53		2	4	10
	Upper Souris	11	14				
	Long Lake	10	41		1		2
	Total	39	108	277	3	4	12
Redhead	Des Lacs	2	4				1
	Upper Souris		2				
	Long Lake	3					
	Total	5	6	120			1
Ruddy	Des Lacs	4	6				
	Long Lake	1	11				2
	Total	5	17	340			2
Total		3,213	5,182	161	136	141	440

The increase in the proportion of female birds beginning about the middle of August continued until, by September, the sex ratio of the botulism victims was reversed for some species to give a slight excess of females. This may be due to several factors:

1. Reduction in total male population by previous loss.
2. Change in feeding habits of male birds (grain field feeding).
3. Males acquiring new flight feathers and moving to botulism-free areas.
4. Movement of females and young into infected marshes from surrounding smaller brood and nesting waters.

After this report was first prepared there was a late botulism outbreak on Lower Souris Refuge, extending through the latter part of August and to about September 18, 1948. The writer learned of coinciding losses at two other North Dakota water bodies, and there were probably others scattered throughout the State. Since the Lower Souris data illustrate the point that late losses may be highly selective for females of some species they are listed separately (Table 2). Some birds of that sex were still in flightless stages.

In North Dakota, small water bodies and those larger areas with only moderate acreages of emergent vegetation were not very attractive to male dabbling ducks of most species during the flightless period. When botulism outbreaks occurred any time after early June on these habitats the loss of females also probably exceeded that of males.

TABLE 4.—SEX RATIOS (MALES PER 100 FEMALES) OF ADULT BOTULISM-AFFLICTED DUCKS BY MONTHS, 1937–1947

Species	June		July		August		September		Total	
	Number	Sex Ratio	Number	Sex Ratio	Number	Sex Ratio	Number	Sex Ratio	Number	Sex Ratio
Pintail	28	460	1,407	214	2,500	106	150	74	4,085	133
Mallard	67	1,570	596	418	866	154	109	102	1,638	219
Shoveller	7	(130)	200	228	583	149	45	200	835	167
G.W. Teal	5	—	226	480	388	198	56	137	675	250
B.W. Teal	4	—	107	155	525	181	30	131	666	175
Gadwall	1	—	82	64	222	141	11	120	316	115
Baldpate	6	(500)	29	314	96	357	16	60	147	277
Redhead	1	—	1	—	6	(100)	3	—	11	120
Ruddy	0	—	8	(300)	13	333	1	—	22	340
Total	119	750	2,656	248	5,199	133	421	103	8,395	161

SUMMARY

The sex ratio of 9,112 ducks contracting botulism on four North Dakota National Wildlife Refuges between 1937 and 1947 was 161 males to 100 females.

There appears to be no selectivity of sexes as far as *Clostridium* toxin is concerned and the ratio of sexes appearing in the studies is a reflection of the differential utilization. If males were attracted to areas at a time when toxin was potent and available a preponderance of males appeared in the collections.

There was an increase in the proportion of females beginning about the middle of August. It is possible that a significant loss of females in September and October may go almost unnoticed where the birds are scattered in the marsh areas and where losses are on more or less isolated water bodies.

While these data indicate that the

major botulism outbreaks on several North Dakota refuges did not, when considered collectively, result in an excess of males in the population utilizing them, it should be kept in mind that those on certain habitats increased the proportion of males of some species. Both Des Lacs and Upper Souris data showed higher loss of female pintails and shovellers; Des Lacs a higher loss of female gadwalls and Upper Souris of female bluewings.

It is apparent that an examination of losses on a sample of all major sickness areas in the flyway should be made through an entire season if the net influence on sex ratios of the waterfowl population is to be determined with certainty for any given year.

FOOD HABITS OF SHOAL-WATER DUCKS ON HORICON MARSH, WISCONSIN*

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PROBLEM

This report is an attempt to describe the seasonal food habits of 172 shoal-water ducks subjected to varying degrees of hunting pressure in the vicinity of Horicon Marsh in southern Wisconsin. Although an extensive survey was made by Martin and Uhler (1939), the analyses of stomach contents of birds collected in various parts of the United States obviously masks the considerable localized variation in the feeding habits of these animals. Local studies, however, also have several limitations. (1) Stomachs from migrating birds may contain foods taken in some relatively distant area. (2) Hunting pressure may alter normal feeding habits, forcing birds to take foods normally avoided (Stoudt, 1944). (3) The size of an area where cover type can be accurately correlated with food-habits depends upon the quality and quantity of available foods. A lower degree of availability will cause ducks to increase their cruising radius in a search for suitable feeding areas. (4) A plant census often does not actually indicate the availability of foods, since the seeds of many plants will remain dormant in the soil for several years until the environment is suitable for germination (Bibbey, 1948).

METHOD

A census of submerged aquatics was taken in order to investigate their comparative availability. The water-covered areas were traced from a cover map of the marsh upon transparent sectional diagrams, which were divided into $2\frac{1}{2}$ acre squares. The aquatic areas were then traversed by boat and the various plant types mapped. An excessive discrepancy seemed to exist between the occurrence of certain seeds in duck stomachs and their availability, suggesting that at least some ducks were feeding away from the study area

* Contribution of Pittman-Robertson Project 8-R.

TABLE 1.—FOOD HABITS OF SHOAL-WATER DUCKS ON HORICON MARSH, WISCONSIN

Food Items	Early Fall[1] (96 Ducks)				Late Fall[2] (31 Ducks)				Spring[3] (23 Ducks)			
	%	Vol.	%	Occ.	%	Vol.	%	Occ.	%	Vol.	%	Occ.
Scirpus spp. (Bulrush)		48		94		26		90		15		100
Scirpus sp.	81		92		38		82		84		96	
Scirpus fluviatilis	19		55		62		61		16		57	
Potamogeton spp. (Pondweed)		12		64		27		45		7		29
Potamogeton sp. (large seed)	61		80		14		51		T		50	
Potamogeton sp. (small seed)	39		62		86		79		T		63	
Potamogeton pectinatus									100		13	
Ceratophyllum demersum (Coontail)		5		35		19		45		13		22
Ceratophyllum demersum (seeds)	73		88		72		86		37		60	
Ceratophyllum demersum (lvs.)	27		24		28		21		63		60	
Quercus sp. (Oak)		4		2								
Polygonum spp. (Smartweed)		2		64		2		42		15		57
Polygonum Hydropiper	56		17									
Polygonum lapathifolium	34		75		50		92		39		85	
Polygonum amphibium	5		2									
Polygonum Persicaria	5		2						T		8	
Polygonum coccineum					50		16		31		39	
Polygonum punctatum					T				30		23	
Alisma plantago-aquatica (Water plantain)		2		3		T		3		2		17
Phalaris arundinacea (Reed canary grass)		2		1						T		4
Lemna spp. (Duckweed)		T		8		2		23		6		26
Lemna trisulca	100		100		78		71		95		33	
Lemna minor					22		71		5		83	
Sparganium spp. (Bur reed)		1		4		T		13		6		17
Sparganium eurycarpum	100		50				50		100		100	
Sparganium sp.	T		50		100		50					
Avena sativa (Oats)						3		3				
Cuscuta sp. (Dodder)		1		14		T		6				
Graminae (Grass)—(lvs.)		1		3						T		4
Leersia oryzoides (Rice cut grass)		1		9		T		3		5		26
Chara sp. (Stonewort)—(Oogonia)		1		2								
Carex sp. (Sedge)		T		29		1		42		3		61
Insecta (Insect)		T		15		T		6		6		57
Triticum aestivum (Wheat)						1		3				
Eleocharis spp. (Spike rush)										3		39
Debris		19		41		19		13		18		52

[1] The items which amounted to *trace* in early fall were: *Polygonum pennsylvanicum*, *Polygonum* sp., Gastropoda, *Claviceps purpurea*, *Myriophyllum* sp., *Bidens* sp., *Sium suave*, *Echinochloa crus-galli*, *Setaria glauca*, *Asclepias* sp., *Galium* sp., *Brasenia Schreberi*, *Sagittaria* sp., *Phleum pratense*, *Rhus* sp., *Ambrosia artemisiifolia*, lead shot.

[2] The items which amounted to *trace* in late fall were: Gastropoda, *Claviceps purpurea*, *Myriophyllum* sp., *Bidens* sp., *Sium* sp., *Galium* sp., *Prunus serotina*, *Cornus* sp., unidentified leaf, lead shot.

[3] The items which amounted to *trace* in the spring were: *Polygonum sagittatum*, Gastropoda, *Claviceps purpurea*, *Bidens* spp., *Galium* spp., *Sagittaria latifolia*, *Calamagrostis canadensis*, *Agrostis alba*, *Acorus* spp., *Lycopus* spp., *Scutellaria* spp., *Gammarus* spp.

or that a considerable quantity of seeds was lying dormant in the soil.

It was concluded that palatability ratings derived from the available information would be inaccurate. The standard volumetric procedure, as prescribed by the Fish and Wildlife Service, was used in making all analyses.[1]

Table 1 is a summary of the food habits of shoal-water ducks during the three periods of concentration on Horicon Marsh. Table 2 is a summary of wood-duck food habits on this same area.

[1] I am indebted to Dr. A. C. Martin, Patuxent Wildlife Research Refuge, for his assistance in identifying unknown items. A. Baldwin, Madison, Wisconsin, assisted in the census and analyses.

RESULTS AND DISCUSSION

Bulrush, *Scirpus* spp., was the genus most used for food in this area during the periods studied. It also was one of the most abundant. Pondweed, *Potamogeton* spp., increased in importance from early to late fall and then decreased considerably in the spring. Fruiting forms of this species are scarce on Horicon Marsh, and its low occurrence in the spring is possibly due to lack of hunting pressure which drove the ducks from the marsh in the fall. Coontail, *Ceratophyllum demersum*, became more important in late fall and spring. The leaves were more heavily used than seeds in spring, possibly indicating a lower palatability than seeds which were undoubtedly less abundant than in the fall. Smartweeds, *Polygonum* spp., relatively unimportant in the fall, were almost as heavily used as bulrushes in the spring. This is important, since they possibly take the place of foods which are more commonly eaten in the fall and are scarcer in spring. Other items which became relatively important in the spring as substitute foods were insects (usually aquatic larvae), greater bur-reed, duckweed, rice cut-grass, sedge, spikerush, and water plantain. Wild rice was not found in any of the stomachs examined. There was a 40 acre stand of rice on the marsh but blackbirds removed most of the grains before the hunting season.

TABLE 2.—FALL FOOD HABITS OF 22 WOOD DUCKS ON HORICON MARSH, WISCONSIN

Food Items[1]	%	Vol.	%	Occ.
Quercus spp.		65		41
Quercus sp. (Oak)	58		67	
Quercus bicolor (Swamp White oak)	42		33	
Sparganium eurycarpum (Greater bur-reed)		16		45
Leersia oryzoides (Rice cut-grass)		6		9
Ceratophyllum demersum		4		23
Ceratophyllum demersum (Coontail)—(lvs.)	75		20	
Ceratophyllum demersum (Coontail)—(seeds)	25		80	
Scirpus spp.		3		64
Scirpus fluviatilis (River bulrush)	75		36	
Scirpus sp. (Bulrush)	25		93	
Potamogeton spp.		2		50
Potamogeton sp. (Pondweed)—(Small seeds)	60		91	
Potamogeton sp. (Pondweed)—(Large seeds)	40		18	
Lemna spp.		1		23
Lemna trisulca (Star duckweed)	86		100	
Lemna minor (Lesser duckweed)	14		40	
Tuber (Unidentified)		1		5
Insecta (Insect)		1		18

[1] The items which amounted to *trace* were: *Carex* spp., *Polygonum Hydropiper*, *Polygonum lapathifolium*, *Polygonum Persicaria*, *Cuscuta* sp., *Myriophyllum* sp., *Alisma plantago-aquatica*, *Sagittaria* sp., *Bidens* sp., *Geum* sp.

No imminent danger of lead poisoning was indicated since only 5 of the stomachs analyzed contained lead, more than a single shot occurring in only one duck.

The importance of ergot, *Claviceps purpurea*, to waterfowl is not known at this time. It is a disease of rye and other grasses which is well known because of the poisonous effect of a horny

mass of thick-walled resting hyphae, called sclerotia. It is slightly irritating to mucous membranes and raw surfaces. In poisonous doses ergot causes violent gastroenteritis, gangrene, and contraction of the uterus (Milks, 1943).

The value of snails is not indicated in this analysis. They were not measured volumetrically because of their use as a source of grit as well as food and the resultant persistence of the shells in the stomachs through several meals. Their importance as a supplement to sand or gravel is indicated by the fact that they comprised the only source of grit in 6 stomachs and most of the grit in 20 others.

Martin and Uhler (op. cit.) indicated sedges as having a slight to fair value as food. This study supports that rating, since the seeds were little used in spite of the fact that sedges were one of the main types of emergent vegetation on the marsh.

It was observed that the food habits of wood ducks varied considerably from those of other species. Oaks and greater bur-reed, relatively unimportant to other ducks, received the highest ratings; while the bulrushes, which were most heavily used by the other shoal-water ducks, were lightly consumed by the "woodies." None of the stomachs of this species contained even a trace of snails.

SUMMARY

1. Hunting pressure, availability of food, cruising range of the birds and dormant seeds are factors which must be considered in establishing palatability ratings for duck foods.

2. Bulrush seed was the most important food on Horicon Marsh, Wisconsin, during the fall and spring of 1947–1948.

3. Items which were important in the spring as substitutes for more palatable foods were insect larvae, greater bur-reed, duckweed, rice cutgrass, sedge, spikerush and water plantain.

4. Wild rice was not found in any stomachs, since blackbirds removed most of the grains in a small area before the hunting season.

5. No imminent danger of lead poisoning was indicated since only 5 out of 172 stomachs contained lead and more than a single shot occurred in only one stomach.

6. Snails were valuable as food as well as a substitute for grit.

7. Sedges, although a common component of typical marsh flora, were almost useless as a source of duck food during the fall and spring.

8. Little competition was indicated between wood ducks and other shoal-water ducks.

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THE EFFECTS ON PHEASANTS OF CORN TREATED WITH VARIOUS FUNGICIDES

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It is a well-established fact that pheasants pull and consume newly planted corn. Knowing that most farmers in Ohio now treat their seed corn with fungicides as a "damping-off" preventive, many sportsmen and game administrators have thought that the fungicides may have been a factor in the recent decline of pheasants. In 1947, based on the results of extensive and intensive studies, pheasants were believed to be no more than one-third as abundant in Ohio as in the 1941–1943 period. The fact that the common usage of fungicides on seed corn came at the same time as the major pheasant decline, helped strengthen this belief.

Faced with numerous inquiries concerning this problem from Ohio sportsmen and from game administrators of other pheasant states, the Ohio Division of Conservation and Natural Resources requested the Ohio Cooperative Wildlife Research Unit to make a study to determine the effects, if any, of treated seed corn on pheasants. Accordingly, a project was initiated in June 1947. The results of the project, which ran through June 1948, are summarized here.

It was found that seven materials are commonly used in Ohio to treat seed corn to prevent "damping off." These materials and their chemical contents are as follows:

1) "Barbak C," composed of mercuric phenyl cyanamide, not less than 8 per cent (equivalent to 3.6 per cent metallic mercury); cadmium oxide, not less than 1 per cent (equivalent to 0.88 per cent metallic cadmium); and inert ingredients, not more than 91 per cent.

2) "Barbak D," composed of mercuric phenyl cyanamide, not less than 6 per cent; cadmium oxide, not less than 1 per cent (equivalent to 0.87 per cent metallic cadmium); and inert ingredients, not more than 93 per cent.

3) "Semesan Jr.," composed of the active ingredient ethyl mercury phosphate (mercury equivalent 0.76 per cent) and inert ingredients.

4) "Arasan," composed of the active ingredient tetramethyl thiuramdisulphide, 50 per cent; and inert ingredients, 50 per cent.

[1] The Ohio Division of Conservation and Natural Resources, the Ohio State University, the U. S. Fish and Wildlife Service and the Wildlife Management Institute cooperating.

Messrs. Don Strode and John Babb, Jr. were employed by the Ohio Division of Conservation to assist with the early phases of the work. The cooperation and assistance of Mr. E. R. Nash and his son Baden of the State Game Farm (Urbana) are gratefully acknowledged. Thanks are due also to Dr. C. C. Allison of the Department of Botany and Plant Pathology, the Ohio State University, for assisting in obtaining the fungicides used in treating the corn.

5) "Arasan S.F." (for slurry treatment), composed of tetramethyl thiuramdisulphide, 75 per cent; and inert ingredients, 25 per cent.

6) "Spergon," composed of tetrachloro-para-benzoquinone, 98 per cent; and inert ingredients, 2 per cent.

7) "Spergon" plus DDT, composed of tetrachloro-para-benzoquinone, 96 per cent; technical DDT, 1.2 per cent; and inert ingredients, 2.8 per cent.

"Barbak C and D" are manufactured by the American Cyanamid and Chemical Corporation, "Spergon" by U. S. Rubber, "Semesan Jr." and "Arasan" by DuPont.

From their chemical composition it will be noted that six of the seven materials used for treating seed corn are poisonous. When "Spergon" is used alone, it is harmless, but when mixed with DDT, the mixture is poisonous. To test the effect of the various materials on pheasants, it was thought desirable to simulate, as nearly as conveniently possible, the conditions under which pheasants consume corn in the field, as sprouts from the newly planted corn appear through the surface of the ground. It is at this time that most damage to corn is done by pheasants. Accordingly, corn was treated at the rates recommended by the manufacturers of the various products and then planted preparatory to feeding captive birds known quantities of the corn. Six movable pens (10′×20′ and 7′ high), made of wooden frames and covered with chicken wire netting, were erected at the Urbana Game Farm. Sixty yearling pheasants, including 12 cocks and 48 hens, were furnished by the game farm superintendent, Mr. E. R. Nash. Within each of the six 10′ by 20′ pens were placed 10 small coops into which were placed two cocks and eight hens. In this manner the birds could be treated individually. The birds were banded with metal leg bands so that they could be identified at a later date when the small pens were removed.

Each of five groups of birds was fed corn treated with a different fungicide. The sixth group, used as a control, was fed untreated corn. The fungicides used in the experiment included "Semesan Jr.," "Barbak C," "Arasan," "Arasan S.F." (slurry treatment in which the fungicide is applied by mixing in water), and "Spergon" plus DDT. The DDT is used to keep insects from attacking corn in storage. Corn was fed the captive birds according to the schedule in Table 1 for a period of 13 days beginning July 2. The corn was pulled with the kernel adhering to the green stalk and fed in known quantities to the birds. It is interesting that birds which were given all of the treated corn they would take, seldom consumed more than 30 grains per day and none of them took as many as 40 kernels of the sprouted corn.

One cock bird died July 3 but death was apparently a result of handling as no treated corn had been eaten by the bird. All of the other birds survived the feeding experiment and, externally, they appeared to be in good condition at the end of the 13-day period.

Assuming that natural mortality among a group of pheasants entering their second year of life would be high, and realizing that it would be difficult to procure dead specimens adequately preserved for pathological examination, six pheasants were sacrificed to permit gross and microscopic study as well as

TABLE 1.—FEEDING SCHEDULE, EGG LAYING AND EGG HATCHABILITY OF PHEASANTS USED IN THE EXPERIMENT

Corn Treated With	Bird Number	Sex	Number of Grains Fed Daily	Egg Laying and Reproduction—1948				Remarks
				Date of First Egg Laid	Total Eggs Laid to May 2	Total Eggs Set	Total Eggs Hatched	
Semesan Jr.	19771	Male	*					Died; examined by Dr. Cole
	19778	Male	20					Dead by March 31
	29779	Female	10	April 7	25	20	7	
	23256	Female	10					Examined by Dr. Cole
	11185	Female	20	April 11	12	12	1	
	12779	Female	20	April 7	25	20	12	
	11366	Female	30	April 6	21	20	14	
	24234	Female	30	April 4	23	20	16	Blood sample taken Jan. 28
	21492	Female	*	April 2	24	20	10	
	11154	Female	*					Examined by Dr. Cole
Barbak C	30384	Male	*					Died December 1947
	24276	Male	20					
	19734	Female	10					Died March 29
	30372	Female	10					Examined by Dr. Cole
	23240	Female	20					Dead by March 31
	19838	Female	20	April 3	20	20	16	
	11159	Female	30	April 19	6	6	1	
	23286	Female	30	April 2	14	14	11	
	11126	Female	*	April 2	15	15	10	Blood sample taken Jan. 28
	12762	Female	*	April 2	15	15	6	
Arasan	11400	Male	*					Dead before August 9
	19763	Male	20					
	11133	Female	10	April 3	22	22	13	
	19792	Female	10	April 2	15	15	2	
	12798	Female	20					Dead by March 31
	12784	Female	20	April 4	14	14	0	
	23259	Female	30	April 8	18	18	13	
	23625	Female	30	April 5	19	19	17	
	11385	Female	*					Died January 12
	24239	Female	*					Examined by Dr. Cole
Arasan S. F.	11393	Male	*					
	12992	Male	20					Transferred to Semesan Jr. group March 30, 1948
	11129	Female	10					Dead by March 30
	21097	Female	10	April 17	7	7	5	
	19781	Female	20	April 11	18	18	0	Hen abandoned eggs
	19847	Female	20	April 11	19	19	11	
	11176	Female	30	April 11	7	0	0	Eggs very thin-shelled; not set
	24224	Female	30	April 14	9	9	4	
	23244	Female	*	Arpil 2	16	16	0	
	12984	Female	*					Examined by Dr. Cole
Spergon plus DDT	11399	Male	*					
	†	Male						Died July 3†
	11121	Female	10	April 13	13	13	0	Hen abandoned eggs
	24251	Female	10					Dead by March 31
	10866	Female	20	April 8	19	19	7	
	11187	Female	20					Dead by March 31
	20570	Female	30					Died January 14
	12932	Female	30	April 10	17	17	12	
	12838	Female	*					Examined by Dr. Cole
	30353	Female	*	April 3	23	20	16	
Control group fed untreated corn	12765	Male	‡					
	23558	Male	‡					Dead by March 31
	12761	Female	‡	April 7	22	20	8	
	23620	Female	‡	April 20	12	12	5	
	12755	Female	‡	April 17	9	9	0	Blood sample taken Jan. 28
	11900	Female	‡	April 12	12	12	0	Blood sample taken Jan. 2; Hen abandoned eggs.
	12759	Female	‡	April 10	17	17	9	
	12829	Female	‡	April 10	16	16	9	
	11188	Female	‡	April 9	18	18	11	
	24296	Female	‡					Died in December

* These birds received all of the treated corn they would eat.

† This cock died before he was banded and before he was fed treated corn presumably from injuries received in catching him.

‡ The control group was fed untreated corn.

chemical analyses of the various organs.

The heart, liver, spleen, intestine, kidney, ovary and breast muscle were collected at autopsy by the junior author and sections were fixed in Zenker's or 10 per cent formalin solutions for microscopic study.

Liver and kidney tissues were desiccated *in vacuo* at 85°C., ground finely, and submitted to Dr. W. R. Brode of the Ohio State University's Chemistry Department for inorganic spectroscopic chemical analysis. Since mercury is stored mainly in the kidneys and liver (Lander 1926) these tissues were collected in chemically clean containers for analysis.

PATHOLOGICAL AND CHEMICAL FINDINGS

Pheasant number 24239, fed "Arasan," showed catarrhal enteritis, early lymphomatosis of the liver, and slight degeneration in the renal tubular epithelium.

Pheasant number 12984, fed "Arasan S.F.," was destroyed on 7-19-47. The autopsy revealed numerous *Heterakis* spp. in the ceca, catarrhal-hemorrhagic enteritis, and cecitis. Glomerular swelling and pyknosis of the nuclei in both the tubular and glomerular epithelium were the only lesions observed microscopically. Less than 0.01 per cent mercury was detected in the liver and kidneys by spectroscopic analysis.

Pheasant number 11154, fed "Semesan Jr.," showed catarrhal enteritis and a few *Heterakis* spp. when destroyed on 8-9-47. Fatty degeneration of the liver and marked degeneration and necrosis of tubular and glomerular epithelium of the kidneys were observed. Many epithelial cells were found free in the lumina of the convoluted tubules. Chemical analysis revealed less than 0.01 per cent mercury in the liver and kidneys.

No lesions were observed in pheasant number 19771 which was given "Semesan Jr." Pheasant number 23256, given the same drug, showed catarrhal enteritis and submucosal hemorrhages in the duodenum when destroyed on 8-9-47. Lymphomatosis affecting the heart, liver, spleen and kidneys was the only prominent microscopic lesion.

Pheasant number 12838, fed "Spergon" and DDT, was destroyed on 7-19-47. At autopsy a catarrhal-hemorrhagic enteritis was noted and histopathological study of the kidneys, liver, and ovaries revealed no abnormalities except lymphomatosis in the liver. Chemical examination was negative for significant quantities of inorganic poisons. Less than 0.01 per cent mercury by weight of dried liver and kidney samples was detected.

Pheasant number 30372, fed "Barbak C," was destroyed on 8-9-47. Fatty degeneration and necrosis were observed extensively in the myocardium. The liver showed fatty degeneration. Lymphomatosis was prominent in the liver, spleen, and ovary. The heart lesions along with the degeneration and necrosis of renal glomerular and tubular epithelium were similar to those observed by Schwarte (1948) in mercury poisoning in geese. Perhaps much of the mercury ingested (Barbak C) was eliminated before the pheasant was killed since less than 0.01 per cent mercury by weight of dried liver and kidney tissue was found by spectroscopic chemical analysis.

In the interpretation of the chemical analyses, the liver and kidneys from pheasants, numbers 12838 and 12984, might be considered as controls for later analyses for the presence of mercury in liver and kidneys from pheasants numbers 11154 and 30372. This is true because pheasants 12838 and 12984 received drugs containing no mercury whereas pheasants 11154 and 30372 were given drugs which did contain mercury. Since less than 0.01 per cent of mercury was found in the dried samples from both groups of pheasants it seems logical to assume that either very little of the mercury-containing fungicides was absorbed or it was eliminated from the body before the samples were collected.

The consistent finding of inflammation in the intestine may be attributed to the ingestion of an irritating substance or to a change of feed and confinement.

Four of the seven pheasants examined showed autonomous proliferation of the precursors of leukocytes in various organs which is characteristic of a disease known as lymphomatosis or leukosis.

"Spergon" and DDT, at the rate given, apparently was not detrimental since pheasant 12838 showed neither symptoms nor lesions directly attributable to those drugs. Rubin, Green, and Carter (1947) studied the toxicity of DDT to laying hens and recorded the following symptoms in hens fed at the rate of 0.125 per cent DDT in the diet for 12 weeks: Loss in weight, molting, tremors, incoordination of the legs, a desire to rest on keel or side, twisting of the neck, and emaciation. The above symptoms were not manifested by pheasants given "Spergon" and DDT.

Rubin *et al.* (1947) reported reduced egg production and hatchability in hens fed 0.062 per cent of DDT in the diet for 12 weeks. Those fed 0.031 per cent DDT showed less severe reduction in egg production while hatchability was not adversely affected.

Pheasants (12984 and 24239) fed "Arasan" showed some kidney lesions, but since they were not extensive it seems unlikely that the health of the birds would have been permanently affected.

Of the three pheasants given "Semesan Jr." (11154, 19771, 23256), pheasant number 11154 showed the most significant lesions. This bird had been given all of the treated corn she would eat. Severe damage was noted in the kidneys which was similar to the lesions described by Boley, Morrill, and Graham (1949) in mercurial poisoning of calves.

Several birds died during the winter, but death was believed attributable to leukosis, which we found to be a common disease, or possibly to the decreased function of the kidneys as a result of ingestion of poisonous substances. It is possible to ascertain to a certain degree the functional ability of the kidneys by quantitative determination of uric acid and non-protein nitrogen in the blood of the bird. Therefore, blood samples were taken from four of the birds January 28, 1948, for analysis.

From the results obtained in analyzing the four blood samples, it seemed that factors other than damage to the kidneys due to fungicides were operating. The junior author concluded that the effect of lymphomatosis on the

kidneys was equally as important as those effects due to the fungicides; therefore, we were actually not measuring interferences to kidney function due to the detrimental action of the fungicide alone.

OBSERVATIONS ON MORTALITY AND PRODUCTIVITY

In March 1948, the 39 pheasants, which still survived, were moved to larger (20′×20′×7′) laying pens in preparation for the tests on egg laying. Of the 10 cock pheasants which were used in the project one had died, as noted above, as a result of injuries on July 3, and five more had died during the fall and winter. Of the 48 hens, 6 had been sacrificed for examination and 9 had died of other causes, presumably of lymphomatosis, at least in part. Omitting the birds that were killed for examination, and the cock that was injured in handling, the following losses occurred between the first and second year of life in these birds: Cocks, 50.0 per cent; and hens, 21.4 per cent. Mortality occurred in the various groups as follows: "Semesan," two males; "Barbak C," one male and two females; "Arasan," one male and two females; "Arasan S.F.," one female; "Spergon" plus DDT, three females; and the control group, one male and one female. It is probable that some of the sacrificed hens would have died anyway as the more unhealthy appearing birds were selected for examination. Mr. E. R. Nash (in conversation, June 29, 1948) commented that when yearling birds were held for a second laying season the usual loss approximated 30 per cent. Because of this high mortality it is no longer the policy of the Ohio Division of Conservation to keep hen pheasants on the game farm for a second laying season.

Prior to egg laying, coops were placed in the large holding pens for each hen so that the eggs laid by each hen could be counted and kept separate for incubating. The cocks were allowed to roam throughout the 20′×20′×7′ holding pen and the hens were taken out of their coops in rotation so that the eggs could be fertilized. Inasmuch as no cock remained in the "Semesan Jr."-treated group, a cock was transferred to this pen from the "Arasan S.F." pen.

The first eggs were laid April 2 (Table 1), whereas the first egg in the large laying fields on the game farm was found March 26. Egg laying by the birds used in this experiment was slightly later than that by the yearling game farm birds as a group, although Mr. Nash indicated in conversation (June 29, 1948) that two-year-old birds usually laid earlier than yearlings.

On May 2, 1948, a wind storm wrecked the laying pens, killed some of the birds and liberated the remainder so that no further observations could be made on egg laying. From April 2 to May 2, however, the 33 hens had laid a total of 542 eggs. The egg laying rate varied from one egg per day to one egg for more than three days. The average number of eggs laid per hen for each group, the average percentage of eggs that hatched, and the interval between eggs, in days, are indicated in Table 2.

DISCUSSION AND CONCLUSIONS

At the beginning of the study no published accounts were found which indicated the effect of various fungicides on pheasants. Taylor (1947) described

the sickness and death of nine hogs evidently as a result of eating seed corn that had been treated with "Semesan Jr." at the rate of one ounce to each bushel of corn. Middleton (1947) reported ethyl mercury phosphate poisoning of cattle which occurred when oats previously treated with "Ceresan" were dumped on the pasture.

Apparently about the same time as the Ohio project was initiated, however, other states, including Iowa, Minnesota and Nebraska, conducted similar experiments with fungicides. For example, Norman J. Ordal of the Entomology Department, University of Minnesota, experimented with "Semesan Jr." and "Ceresan" on pheasants. He stated (in litt., May 18, 1948): "My data indicates that the possibility of damage to birds in the wild is remote. I found that force feeding large single dosages of the compounds containing on the order of 10 mgs. Hg. per Kilogram killed the birds. However, if smaller daily dosages were administered a greater amount was necessary to cause death. Birds fed a straight diet of treated corn were in apparent good health at the end of the forty-five day period."

Working in Iowa, Dr. Thomas S. Baskett, now of the Missouri Cooperative Wildlife Research Unit, also found that pheasants were not critically affected by corn treated with "Semesan" or with "Arasan" until at least 10 times the normal dosages were fed (in litt., August 4, 1948).

Although the Ohio experiments indicated that some lesions were apparently produced in the kidneys and hearts of three of the sacrificed pheasants it is doubtful if the damage was serious enough to have resulted in their death. It can be concluded that at the rate and under the conditions which the various fungicides were given, "Barbak C" was the most toxic, followed by "Semesan Jr." which also produced detrimental effects, "Arasan" which produced only mild temporary lesions, and "Spergon" plus DDT which caused no apparent lesions. It is interesting to note that although the most toxic drugs contained mercury in their formulae less than 0.01 per cent by weight of the dried samples of livers and kidneys was composed of mercury as determined by spectroscopic quantitative analysis.

Throughout the experiment, pheasants in the various experimental and control groups died in about the same proportion, indicating that there were apparently no delayed or accumulative

TABLE 2.—EGG LAYING RATES AND HATCHABILITY OF EGGS ACCORDING TO VARIOUS GROUPS

Group	Average Number of Eggs Laid per Hen*	Average Interval Between Eggs in Days	Percentage of Eggs Producing Live Chicks†
Semesan Jr.	21	1.24	53.6
Barbak C	14	1.89	62.9
Arasan	18	1.57	51.1
Arasan S.F.	13	1.72	39.2
Spergon plus DDT	18	1.36	62.5
Control	15	1.38	45.6

* Observations on egg laying were terminated because of storm damage, May 2.
† Eggs which were abandoned by the chicken hen used for incubating them were not included in these tabulations.

detrimental effects resulting from the consumption of the treated corn. There was no clear-cut difference in the average number of eggs laid by the groups of treated birds as compared with the control birds. Also, with the exception of the "Arasan S.F." group of hens, the percentage of eggs producing live chicks was greater among the treated birds than the control group. These facts provide further evidence that the consumption of corn treated with fungicides at the rate recommended by the manufacturers is not likely to be a serious factor in pheasant mortality or pheasant production. Even assuming that the treated corn were consumed in quantities sufficient to be lethal it is doubtful if the percentage of female pheasants that pull corn (and hence are susceptible to poisoning) would be great enough over the pheasant range to greatly influence pheasant population trends.

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EFFECTS OF ALFALFA MILL CUTTING ON PHEASANTS AND OTHER WILDLIFE IN WOOD COUNTY, OHIO, 1946–1947

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In 1943, Ohio pheasant populations entered a series of unfavorable years characterized by a drastic reduction of numbers. The condition persisted through the period of this study, and it has been a major aim of conservationists and game men to promote rapid restoration of pre-war abundance.

Alfalfa, which is an important pheasant nesting cover, is widely distributed in the cash grain-crop area of the State, and pheasant mortality due to haying operations is widespread in the major

[1] The Wildlife Division of the Ohio Department of Natural Resources, the Ohio State University, the U. S. Fish and Wildlife Service and the Wildlife Management Institute cooperating.

Acknowledgement is due Kenneth J. Chiavetta, Roland B. Handley, Roy N. Hooker, Richard L. Longfellow, Jack D. Remington, Harold E. Warvel, and William E. Wiseman who assisted in gathering the field data. Special thanks are due Dr. Daniel L. Leedy for his guidance in the study, field assistance, and aid in the preparation of this paper. The editorial assistance of Dr. Joseph P. Linduska is gratefully acknowledged.

pheasant counties. The ever-increasing number of alfalfa dehydrating mills in certain counties of Ohio's best pheasant range was considered by many to be one of the most serious menaces to pheasant restoration in these localities. As part of the 1946–47 intensive pheasant nesting study an attempt was made to determine the severity of pheasant mortality caused by alfalfa mill mowing.

WOOD COUNTY ALFALFA DEHYDRATING MILLS

During the two years of study there were seven alfalfa dehydrating plants located in Wood County, Ohio. In 1946, two of the mills began operations May 1, and the others at later dates. In 1947, all mills began operations between the first and the middle of June. With the exception of short intervals of delay caused by inclement weather, mill operations were on a 24-hour a day basis. Cutting took place day and night and continued throughout the haying season until hay growth slackened, or until frosts damaged the alfalfa foliage.

Power mowers, employed by each mill to do the cutting, were attached to various types of tractors and were operated at speeds of 6 to 8 miles per hour. Immediately after cutting, the hay was loaded and transported to the home mills, where the moisture was removed by artificial heat. The value of artificial dehydration lies in the greater nutritive value of the cured product as compared to field-cured hay.

In general, the cutting for each mill ranged extensively over the entire county, and was done wherever the mill contracting agents and the farmer-landowners could reach agreements.

METHODS

During the 1946 pheasant reproductive season in Wood County, Ohio, a sample of 565 acres of first cutting alfalfa, 196 acres of second cutting, and 23 acres of third cutting were thoroughly checked for pheasant nests and mortality immediately after the hay was removed from the fields. The 1946 sampling involved 23 fields totaling 784 acres in six townships of the county. Fields ranged in size from 7 to 100 acres. In 1947, 350 acres of first cutting alfalfa, 151 acres of second cutting, and 59 acres of third cutting were checked. This sample comprised 27 fields totaling 560 acres in five townships. Fields ranged in size from 6 to 65 acres.

It was possible to obtain information concerning pheasant nests and mortality which had heretofore been recorded only in part. Previous conclusions were in most instances based on farmer-harvested hay fields where the hay was left on the ground to field-cure. In the latter type of "haying" there is a period of from one to several days during which time data cannot be obtained. During this time scavengers and predators such as dogs, domestic cats, marsh hawks, raccoons, opossums, crows, and turkey vultures may devour or carry-off dead and crippled birds. Damage done to nests by these species renders accurate determinations on clutch size, degree of incubation and fertility extremely difficult. Since dehydrating mills cut and remove the hay in a green condition (uncured), it is possible to gather the data immediately after cutting.

It should be emphasized that the pheasant mortality rate resulting from

farmer "haying" activities does not parallel that of dehydration-mill mowing where cutting operations generally proceed day and night. Two factors are responsible for a much greater casualty rate in mill-cut alfalfa: (1) excessive speeds of power mowers and, (2) night cutting operations which kill many more juvenile pheasants. The use of power mowers by farmers is becoming more prevalent, but farmers usually do not attain cutting speeds comparable to mill mowers, nor is any appreciable amount of hay cut by them at night.

Each mowed field was surveyed on foot. A stripping system was employed which enabled the observer to record essentially all nests and casualties occuring in the field. All fields were examined as soon as possible after the hay had been removed. Frequently the fields were checked in the wake of the loading machines. A few nests might have been overlooked due to obliteration by the wheels of the hay harvesting machinery, and some individuals, especially juveniles, might have been loaded with the hay.

Pheasant nests, located in fields cut by mill mowers, were scrutinized, and information on the number of eggs, degree of incubation, fertility and nest placement in the field was noted. All observed pheasant casualties caused by cutting operations were recorded. Inasmuch as some birds were picked up by the loading equipment the mortality figures in this report are conservative. Usually however, some remnant of a pheasant's body was left in the field. This was particularly true of incubating hens, inasmuch as the legs and feet were quite often left at the nest site even though the rest of the body had been removed with the hay. When only one leg or foot was found at the nest site the hen was considered crippled; but when two legs were found the hen was recorded as killed. Data pertaining to adult and juvenile molt, food habits, and condition of ovaries were obtained from intact specimens.

PHEASANT CASUALTIES RESULTING FROM ALFALFA MILL MOWING

Total Pheasant Casualties

In a sample of 784 acres of mowed alfalfa surveyed in 1946, 128 hen pheasants were killed, 5 were crippled, and 85 juveniles were killed. One casualty was represented in each 3.6 acres of alfalfa cut. The greatest mortality in any one field was found in a 23-acre field in close proximity to the Liberty Township State Game Refuge. Here, 55 pheasants were killed as a result of three mowings; 29 hens in the first cutting, 4 hens and 12 juveniles in the second, and 10 juveniles in the third cutting.

In 1947, 74 hens were killed and 9 were crippled; 27 juveniles were killed and one was crippled in a sample of 560 acres of mill-cut alfalfa. One pheasant casualty was represented in each 5.5 acres of alfalfa cut.

The number of hen casualties decreased from June to July 1946, and increased during this same period in 1947. Early hatching, desertion of nests due to flooding, and no appreciable late nesting during 1946 undoubtedly accounted for much of this difference between the two years.

Juvenile casualties did not become

apparent until June of both years. In mill-cut alfalfa the first hatched nest was found on June 22, 1946; and on June 20, 1947. A few more juvenile casualties were found in June 1946 than in June 1947.

On the basis of the two-year study some idea can be had concerning the overall picture of pheasant casualties resulting from mill mowing. There were approximately 26,259 acres of alfalfa in 1946, and 24,650 acres in 1947 reported cut by six of the seven alfalfa mills located in Wood County, Ohio. The pheasant casualty rate per acre of greatest during those periods of most intense incubation. The hen casualty rate noticeably declined immediately following a period of heavy rains and flooding (June 11–20, 1946) and gradually built up to a secondary level during the first half of July. This temporary decline was probably due to a large number of hens deserting their nests, and an almost complete absence of nest establishment during and immediately following this period of inclement weather.

Data collected in mill-cut hay fields revealed that incubating hens were

TABLE 1.—THE COMPUTED NUMBER OF PHEASANT CASUALTIES RESULTING FROM THE MOWING ACTIVITIES OF SIX ALFALFA MILLS IN WOOD COUNTY, OHIO, 1946–47

Year	Computed Number of Hen Casualties				Computed Number of Juvenile Casualties				
	Cutting			Total	Cutting			Total	Grand Total
	1st	2nd	3rd		1st	2nd	3rd		
1946	1,604	814	0	2,418	435	2,673	2,721	5,829	8,247
1947	1,857	686	0	2,543	311	930	104	1,346	3,889

sampled alfalfa for each of the three cuttings if multiplied by the acreage of total hay reported cut during each of the three cuttings gives an estimate of the total number of casualties for the entire season as a result of mill mowing activities. Table 1 shows the computed number of hen and juvenile pheasant casualties for each of the three cuttings based on the hay mill reports and the samples taken during 1946–47.

Hen Pheasant Mortality

In 1946 and 1947 hens were found killed or crippled only in first and second cuttings of alfalfa. No nests or hen casualties were found in the third cuttings during both years. The hen casualty rate for the two years was more vulnerable to the cutter-bar than were laying hens. A comparison of the hen casualty rate with the stage of nesting reveals that in mill-cut alfalfa fields sampled throughout the 1947 pheasant nesting season, 46 incubating hens were actually found killed or crippled at their nest sites. In 39 nests where incubation was in progress (hatched nests not included) no dead or crippled hens were found. No hens were found at 42 nests in which the hens were still laying or had not started to incubate. Mortality undoubtedly occurred at many of those nests in which eggs were being incubated, even though no mortality was found at the nest sites. In all probability, however, these hens were able to move, or were transported

by the haying operations some distance from the nest sites. More than 50 per cent of the incubating hens included in the sample were casualties of the cutter-bar, whereas laying and non-incubating hens were seldom if ever injured. Severed legs were never found at nests in which incubation had not yet begun. This may be taken as further evidence that laying hens are less vulnerable to mill mowing.

The relationship between casualties of adult females and nesting is shown in Figure 1. The hen-casualty rate for 1946 is shown in semimonthly periods throughout the mill-cutting season. Also shown is a line graph displaying the rate of nest establishment for these semimonthly periods. The nest-establishment curve was determined by

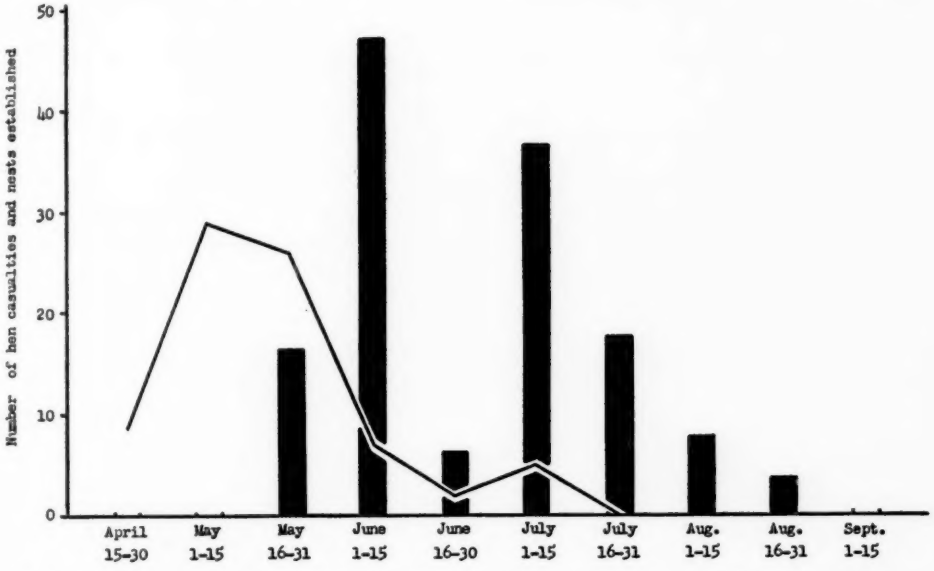

FIG. 1. The trend of nest establishment (represented by curve) compared with the number of hen casualties occurring per 100 acres (represented by bars) in mill-cut alfalfa, 1946.

Hen pheasants were killed during the month of August 1946 even though no active pheasant nests were found subsequent to the July 1–15 period. In 1947, however, no hen mortality was found after July. The casualties during August 1946 were suffered by hens, which with their young, were inhabiting fields of alfalfa. In 1947, the cover in August appears to have differed in such a way that family groups in the sampled region did not utilize any appreciable amount of alfalfa during their development.

computing the date on which the first egg of the clutch was laid. This figure shows that the peak of nest establishment and egg laying preceded the first evidence of hen mortality, further substantiating the observation that few if any hens were killed during the period of egg laying. The period between the peak of nest establishment and the onset of hen mortality (May 1–15 to May 16–31) marks the period of early egg laying.

Juvenile Pheasant Casualties

Juvenile casualties in mill-cut alfalfa did not become evident until June of both years. Earlier nests located in cover types other than alfalfa were known to have hatched prior to June, but these broods apparently did not shift to alfalfa. Observations indicate that the majority of juvenile pheasants killed in alfalfa prior to July have been

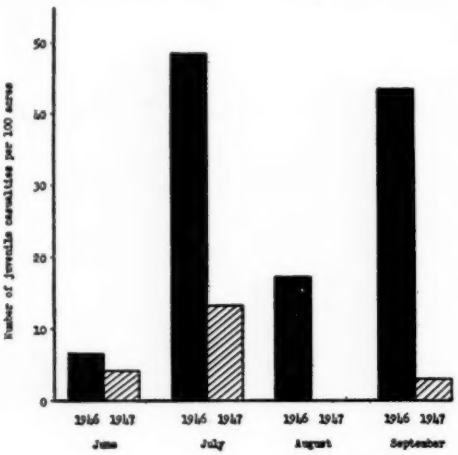

FIG. 2. Monthly juvenile pheasant casualty rate per 100 acres in mill-cut alfalfa, 1946–47.

hatched there. This seems to be especially true in the case of extremely young birds, since their activities were observed to be confined to a relatively small area in the immediate vicinity of their hatching locations.

Figure 2 compares the juvenile pheasant casualty rates for 1946 and 1947 in mill-cut alfalfa on the basis of the number of pheasants killed or crippled per 100 acres mowed. Without exception, more juveniles were killed or crippled in any month in 1946 than in the corresponding month of 1947. The 1947 reduction in the number of juvenile pheasant casualties in mill-cut alfalfa suggests a decrease in the reproductive efficiency and/or a decreased nesting intensity in the sampled alfalfa fields. The latter factor apparently had little effect since the number of nests found per acre in mill-cut alfalfa was nearly the same during both years: 4 acres per nest in 1946, and 3.5 acres per nest in 1947. However, it was found that a greater number of nests were successful in 1946 despite the destruction caused by flooding. In 1946, 12 per cent of 194 nests were successful in 784 acres of mill-cut alfalfa surveyed, but only 6 per cent of 162 nests found in 560 acres of alfalfa were successful in 1947. Thus the reduction in the number of juvenile casualties in 1947 seems to have been associated, in part at least, with the decrease in the reproductive efficiency.

Two factors apparently accounted for the high rate of juvenile casualties during July of both years. Due to continued hatching, a progressively greater number of juveniles were present as the season progressed. Another probable factor was the shifting of broods from wheat and oat fields to alfalfa as a result of small grain harvesting. Nesting was about completed by mid-July.

All age classes of juvenile pheasants were represented in the mowing mortality. In some instances, especially among broods 1–8 weeks of age, a larger number of individuals in each brood was killed or crippled than in older broods. The greater vulnerability of the younger broods might be accounted for by the fact that they were less agile than older birds and also, they tended to remain in more compact groups. The fact that young broods generally had more young per brood

would account for more young birds being represented in the sample. The extent of dispersal and the rapidity of reassemblage, although less obvious, might also have been important.

There was a decided tendency for the hens and juveniles to move toward the center of a field being cut during the daylight hours. Quite frequently the hens would flush in advance of the cutter-bar leaving their young milling about in the path of the approaching mower. At night this movement was less well pronounced, and the birds were often killed as they roosted.

TABLE 2.—PHEASANT CASUALTIES OCCURRING IN ALFALFA CUT FOR ALFALFA MILLS ACCORDING TO TIME OF DAY WHEN CUT, WOOD COUNTY, OHIO, 1946–1947

Time of Day When Cut	Number of Cutting	Number of Acres	Number of Pheasant Casualties	Number of Nests Found	Hen Casualties per 100 Acres	Juvenile Casualties per 100 Acres	Total Casualties per 100 Acres	Hen Casualties per 100 Nests	Juvenile Casualties per 100 Nests	Total Casualties per 100 Nests
Day and Night	First	557.7	126 hens 40 juv.	213	22.6	7.2	29.8	59.2	18.8	77.9
Day and Night	Second	207.5	19 hens 31 juv.	8	9.2	14.9	24.1	23.8	38.8	62.5
Day and Night	Third	39.0	0 hens 1 juv.	0	0.0	25.6	25.6	—	—	—
Night	First	88.2	19 hens 0 juv.	44	21.5	0.0	21.5	43.2	0.0	43.2
Night	Second	17.5	4 hens 20 juv.	0	22.8	114.3	137.1	—	—	—
Night	Third	23.0	0 hens 10 juv.	0	0.0	43.5	43.5	—	—	—
Day	First	112.4	45 hens 4 juv.	76	40.0	3.6	43.6	59.2	5.3	64.5
Day	Second	103.9	4 hens 8 juv.	4	3.7	7.7	11.5	1.0	2.0	3.0
Day	Third	20.0	0 hens 0 juv.	0	0.0	0.0	0.0	—	—	—
Total	Three cuttings	1169.2	217 hens 114 juv.	345	18.6	9.8	28.3	62.9	33.0	95.9

Day Versus Night Mowing Casualties

In an effort to determine whether or not a differential casualty rate existed in night and day mowing a record was kept of the time each field was cut under one of three headings: day cut, night cut, or night and day cut. In the final analysis, shown in Table 2, the number of pheasant casualties occurring in each of the three cuttings is compared with the number of acres cut and the number of nests mowed over during each of the three periods. Adult female casualty rates during day versus night mowing can be computed most readily by comparing the number of casualties with the number of nests mowed over, since the majority of the hen casualties occurred during nest incubation. This was especially true in the first cutting. Juvenile casualties are represented on the basis of the number per 100 acres mowed.

As shown by the sample, the number

of hen casualties per 100 nests mowed over is actually greater in day mowing than at night in the first cutting of alfalfa. Sixteen more hens were killed or crippled per 100 acres as a result of day mowing operations. Approximately 97 per cent of the hen casualties found in this sample occurred in the first cutting. The majority of these were incubating females. No accurate comparison of hen casualties due to day versus night mowing can be made on alfalfa. In night mowing of the second and third cuttings, however, there were respectively 107 and 44 more juveniles killed or crippled per 100 acres than in day mowing.

It is concluded from the sample that night mowing of alfalfa by mill mowers was much more detrimental to juvenile pheasants than to hen pheasants. Also, the time of mowing had little effect upon the casualty rate of incubating hens.

TABLE 3.—A COMPARISON OF THE PHEASANT CASUALTY RATE IN FARMER AND MILL-CUT ALFALFA, WOOD COUNTY, OHIO, 1946–1947

By Whom Cut	Number of Cutting	Number of Acres	Number of Nests	Number of Hen Casualties	Number of Juvenile Casualties	Casualties/100 Nests			Casualties/100 Acres		
						Hen	Juvenile	Total	Hen	Juvenile	Total
Farmer	First	123.3	41	8	4	19.5	9.8	29.3	6.5	3.2	9.7
Farmer	Second	87.8	2	2	1	100.0	50.0	150.0	2.3	1.1	3.4
Farmer	Third	42.4	0	0	0	—	—	—	—	—	—
Total		253.6	43	10	5	23.3	11.6	34.9	3.9	2.0	5.9
Mill	First	758.3	333	190	44	57.1	13.2	70.3	25.1	5.8	30.9
Mill	Second	328.9	12	27	51	225.0	425.0	650.0	8.2	15.5	23.7
Mill	Third	82.0	0	0	11	—	—	—	0.0	13.4	13.4
Total		1,169.2	345	217	106	62.9	30.7	93.6	18.6	9.1	27.6

the basis of the number of nests mowed over in the second and third cuttings because of the small number or complete absence of nests at the date of these cuttings. Hens killed or crippled during the second and third cuttings, for the most part, were associated with broods. Thus, for these cuttings, a comparison on the basis of casualties per 100 acres is more fitting. In night mowing of the second cutting of alfalfa, 23 hens were found killed or crippled per 100 acres compared with only 4 hens found killed or crippled in day mowing. No hens were found killed or crippled in the third cutting of alfalfa.

Little difference existed in the juvenile casualty rate between night and day mowing in the first cutting of

Pheasant Casualty Rates in Farmer and Mill-Cut Alfalfa

An intensive pheasant nesting study was conducted on four square-mile areas in Wood County, Ohio, 1946–47. During this study the pheasant casualty rate was determined in a sample of 254 acres of alfalfa cut by farmers. This acreage represented three cuttings. The sample occurred in the same general area in which alfalfa mill sampling was done. Mowing equipment employed by farmers consisted of power mowers, mowers designed for horses but pulled by tractors, and horse-drawn mowers. It is believed that the sample consisted of a representative cross section of farmers' mowing activities in this region.

Table 3 compares pheasant casualty rates in alfalfa cut by farmers with those in alfalfa cut by mills. On the basis of casualties per 100 acres cut, there were 5 times more pheasants killed or crippled in mill-cut alfalfa than in that cut by farmers. On the basis of 100 nests mowed over, there were 3 times more hens and 3 times more juveniles killed or crippled during mill cutting than in farmer mowing.

DESTRUCTION OF OTHER WILDLIFE

In addition to the pheasant data collected in mill-cut hay fields, notes were also kept on other animal species. Seven species of mammals, seven species of passerine birds, two species of amphibians and one species of reptile were represented in the mowing mortality. No accurate quantitative measurements of the destruction done to songbirds or their nests and young were possible because of their elevated placement in the alfalfa, their small size, or the ease with which evidences of mortality were completely obliterated.

A total of 57 adult and juvenile cottontail rabbits were killed during both seasons as a result of mowing 1,344 acres of alfalfa.

SUMMARY AND CONCLUSIONS

1. The effect of alfalfa mill mowing on pheasants and other wildlife in Wood County, Ohio is given for the years 1946 and 1947.

2. Power mowers were employed by each mill to do the cutting. All fields were surveyed as soon as possible after the hay had been removed, and information concerning pheasants and other wildlife was collected.

3. In 1946, a sample of 784 acres of alfalfa (representing 1st, 2nd, and 3rd cuttings) was checked for pheasant nests and pheasant casualties. This sample included 23 fields ranging in size from 7 to 100 acres in 6 townships in the county. In 1947, a sample of 560 acres was checked. This sample comprised 27 fields ranging in size from 6 to 65 acres in 5 townships.

4. In the 1946 sample, one pheasant casualty was represented in each 4 acres of alfalfa cut. In 1947, one casualty was found in each 6 acres cut.

5. Based on the samples obtained, approximately 2,418 hens and 5,829 juveniles were killed or crippled in 26,259 acres (three cuttings) mowed by alfalfa mill mowers in 1946 compared to 2,543 hens and 1,346 juveniles killed or crippled in mowing 24,650 acres in 1947. It was of interest that no adult cocks were killed in either of these years of study.

6. Incubating hens were more vulnerable to the cutter-bar than were laying hens. In 1947, 50 per cent of the incubating hens included in the sample were known to have been killed or crippled, but laying and non-incubating hens were seldom if ever injured.

7. Without exception, more juveniles were killed or crippled in any one month in 1946 than in the corresponding month of 1947. Since the number of nests per acre remained fairly constant during both years, the difference in the juvenile casualty rate apparently was due to the greater nesting success in 1946: 12 per cent of 194 nests were successful in 1946, whereas only 6 per cent of 162 nests were successful in 1947.

8. All age classes of juvenile pheas-

ants were represented in the mowing mortality.

9. The time of day had little effect on the number of adult females killed or crippled in the first cutting, since the greater portion of this group represented incubating birds. In the second cutting, however, 23 hens were found killed or crippled per 100 acres in night mowing and only 4 hens were represented as casualties per 100 acres in day mowing.

10. There was little difference in the juvenile pheasant casualty rate between night and day mowing in first cut alfalfa, but in night mowing of second and third cuttings there were respectively 107 and 44 more juveniles killed or crippled per 100 acres than in day mowing.

11. Three times more pheasant casualties per 100 nests mowed over occurred in mill-cut alfalfa than in farmer-cut alfalfa. On the basis of casualties per 100 acres cut, there were 5 times more pheasant casualties in mill-cut than in farmer-cut alfalfa.

12. Seven species of mammals, seven of passerine birds, two of amphibians, and one species of reptile were represented in the mowing mortality.

PHEASANT USE OF FOOD AND COVER TYPES, NORTHWESTERN MINNESOTA

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A study by the author (1940) based on observations on range with a low population of pheasants, *Phasianus colchicus torquatus* (Gmelin), in southeastern Minnesota, indicated the importance of various food and cover types in meeting the needs of the species during the critical winter months. The present analysis is based on observation in Northwestern Minnesota (Ottertail, Wilkin and Grant counties) during the winters of 1940–41, 1946–47 and 1947–48.

Kimball (1948) reports the severity of winter losses of pheasants during some years in the Dakotas, and numerous observers (Carlson, 1941) have reported severe winter losses in Minnesota. Deficiencies in food and cover, resulting in a high winter mortality, are believed to be the limiting factors in the management of the ringnecked pheasant in Minnesota during the years of severe winters, and an important factor in other years. The frequency and the extent of the birds' use of specific food and cover types should be an important indication of the merits of those types in meeting the needs of the species.

DESCRIPTION OF AREA

Most of the records were obtained in Ottertail County; a general description of the county will reflect the land use pattern and the general availability of food and cover. The county is located in northwestern Minnesota, twenty miles from the North Dakota line. The soils vary from the level silt and sandy loams of the Red River Valley (Basin of glacial Lake Agassiz) on the west; the well-drained loams of the glacial till

plains and morainic hills and ridges with enclosed lakes and marshes in central; to the sandy, level and choppy moraines on the east. The native forest growth consists of mixed hardwoods, largely bur oak, red oak, birch, aspen, elm and maple. General dairy and livestock farming is practiced. About eighty-five per cent of the land in the county is in farms, and the land use is divided as follows: small grain (oats, wheat, barley, rye, flax) 29 per cent; intertilled (corn, cane, potatoes) 10 per cent; tame hay (alfalfa, timothy, clover) 14 per cent; wild hay 6 per cent; pasture 29 per cent (19 per cent wooded); woodland 5 per cent; and other land 7 per cent. Excepting a narrow strip extending north along the Red River Valley, the county is the northernmost Minnesota county where pheasants occur in abundance.

TABLE 1.—SPREAD OF OBSERVATIONS

Month	Dec.		Jan.		Feb.		March	
Dates	1–15	16–31	1–15	16–31	1–15	16–28	1–15	16–31
No. of Pheasants	123	457	189	466	442	262	246	139

TABLE 2.—TIME OF OBSERVATIONS

	A.M.					P.M.						
Hour of day	8	9	10	11	12	1	2	3	4	5	6	7
No. of Pheasants	31	56	145	160	76	76	398	623	418	268	41	36

RECORDING OBSERVATIONS

Information such as time, number, sex, location, weather, activity, and environmental factors was recorded at the time the pheasants were observed. A decision was made as to the primary and secondary food and cover factors which were responsible for the birds' presence at that particular point and time. If a bird was noted feeding in a cornfield at a point adjacent to a slough, for example, corn was assigned the primary factor and the slough the secondary. However, if the bird were feeding in the cornfield on the opposite side from the slough, then only the corn was assigned as a factor. The assignment naturally requires careful observation and knowledge of existing facts. Only by a large number of observations can misjudgement be minimized. The use of two factors, where apparent, helps to reduce the human element, and provides an opportunity to avoid positive assignments where several factors are involved.

SEX RATIOS, BEHAVIOR, ACTIVITY

The Minnesota pheasant harvest in 1940 (nearly 1½ million) was higher than in any previous year, and the winter population likewise was higher than in previous years. Sex ratios of 30:100 were recorded in 1940–41 and 72:100 in 1946–47–48. Males have a tendency to remain aloof and alone from others of their own sex and species. Twenty per cent of all males observed were

alone, and seven per cent were single males with one or more females. Seven per cent of all females observed were alone, and two per cent were single females with one or more males. A total of 2,328 birds were recorded, and 1,043 were feeding, 688 cruising, 492 resting, 36 roosting, and 69 were not assigned by activity.

DISCUSSION

The importance of corn and sloughs for providing food and cover during the winter months is shown in Table 3; therein lie the important controls of pheasant numbers. Large numbers of pheasants will concentrate in the larger sloughs containing dense stands of cattails (*Typha sp.*) and reed grass (*Phragmites communis*). The sloughs provide escape and roosting cover from which the ringneck cruises to cornfields as far as a mile in distance. The smaller meadows and lowland areas which provide summer and fall roosting grounds are abandoned after the first fall storms, and the birds are forced to the larger sloughs. Severe storms like those of November 11, 1940 and March 15, 1941, caused high mortality among birds. Pheasants without cover were found frozen in a natural roosting position, facing the wind, with beak open. During and following blizzards, they do not leave cover, but concentrate along the south-facing slopes adjacent to the sloughs. Following the March 15th storm, a careful search was made of two sloughs to which over twenty pheasants were seen retiring the night before. Snow had drifted completely over the sloughs. No birds were noted, nor was there evidence of any having dug out. Mortality of this type probably accounts for the greatest loss of birds. Carlson (1941) records similar losses.

TABLE 3.—FACTORS ACCOUNTING FOR THE PRESENCE OF PHEASANTS AT LOCATIONS WHERE OBSERVED

Types of Food and Cover Influencing Occurrence of Birds	Primary	Secondary	Total
Foods:			
1. Corn, standing or shocked	481	183	664
2. Manure spread or piled in fields	254	17	271
3. Uncut legumes, alfalfa, sweet clover	137	7	144
4. Grit-roads, pits, bare spots	100	20	120
5. Weeds, uncut grains	40	35	75
6. Barnyard, straw, grain, manure	71	47	118
7. Straw and hay stacks-field	51	5	56
Cover:			
1. Sloughs, marshes, uncut lowland meadows	516	433	949
2. Woods, mixed hardwoods	222	146	368
3. Brush, shrubs, hardwood reproduction, fence rows	264	91	355
4. Farmstead windbreaks, usually part coniferous	99	67	166
5. Weeds, uncut grains	31	0	71
6. Uncut legumes, alfalfa, sweet clover	27	24	51

The value of manure for food, and the farmstead for both food and cover, suggests pheasant management measures that can be applied by the land owner. Spreading manure near good cover can be accomplished with little

additional effort by the farmer. Few farms have good farmstead windbreaks, but most farmers, even on the more valuable lands, will provide the space and with some encouragement establish windbreaks for the buildings, which will, at the same time, provide a wildlife habitat.

SUMMARY

The use of food and cover types by pheasants in northwestern Minnesota was observed during daylight hours through the winters of 1940–41, 1946–47 and 1947–48. Sex ratios were 30:100 and 72:100. Cocks have a tendency to remain aloof from others of their own sex and species. Pheasants spend most of the daylight hours feeding or cruising. Food and cover factors assigned to birds observed show corn as food and sloughs as cover to be of greatest importance. Manure, in field or barnyard, legumes and grit are important food sources; woods, brush and farmsteads are important sources of cover. Severe winter mortality is reported. Spreading manure near cover and planting farmstead windbreaks are suggested management measures.

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IT'S TIME TO TAKE STOCK

Report by the Wildlife Society Employment Committee

Likening colleges and universities to the automobile industry may seem far fetched, but is it? Each is engaged in fashioning and selling necessary products—one trained men, the other mechanical equipment. Both entered the post-war years with production at low ebb; unable to satisfy pent-up customer demands. Time and high-speed assembly lines have bridged the gap of gas buggy shortage. The impact of selective buying by a discriminating public is now real cause for concern among some of the motor moguls. Rumor has had it that schools teaching wildlife management are overproducing. We decided to gather facts and opinions at the source of supply, and present them to the profession.

As the first step in this operation, colleges and universities giving course work leading to degrees in wildlife management were canvassed. They were asked to supply statistics on degrees granted during the 1948–1949 school year, and enrollments for the fall term of 1949. They were also requested to comment on the status of employment as it affected recent graduates, whether there was need for expanding the employment base, and if so what they were doing about it.

Table 1 shows that 369 undergraduate and graduate degrees were granted during the year ended September 1949. Table 2 discloses that 1,784 students are pointing their collegiate training toward future employment in the various phases of wildlife work.

Advice on the employment status of

TABLE 1.—NUMBER OF DEGREES GRANTED FOR COMPLETION OF STUDIES AT SCHOOLS TEACHING WILDLIFE MANAGEMENT IN THE UNITED STATES, FOR THE YEAR ENDED SEPTEMBER 1949

College or University	Undergraduate Degrees	Master's Degrees	Doctor's Degrees
1. Alabama Polytechnic Institute	0	0	0
2. California University	12	2	0
3. Colorado A & M College	14	2	0
4. Connecticut University	2	0	0
5. Cornell University	9	7	4
6. Idaho University	0	0	0
7. Illinois University	0	4	0
8. Iowa State College	6	5	2
9. Kansas University	1	3	3
10. Louisiana State University	5	0	0
11. Maine University	21	4	0
12. Massachusetts University	1	1	0
13. Michigan University	10	6	0
14. Michigan State College	14	0	1
15. Minnesota University	15	7	1
16. Missouri University	12	2	0
17. Montana State University	7	0	0
18. New Hampshire University	1	0	0
19. New York State College of Forestry	0	2	1
20. North Carolina State College	4	3	0
21. Ohio State University	13	3	4
22. Oklahoma A & M College	13	4	1
23. Oregon State College	32	5	0
24. Pennsylvania State College	0	4	0
25. Purdue University	0	0	0
26. South Dakota State College	11	0	0
27. Texas A & M College	17	1	0
28. Utah State Agriculture College	14	3	0
29. Virginia Polytechnic Institute	18*	1*	0
30. Washington State College	15	0	1
31. Wisconsin University	0	0	1
32. Wyoming University	12	2	0
Totals	279	71	19

* Includes both Forestry and Wildlife.

students who graduated during the year ended September 1949, and obtained wildlife employment, was requested in our questionnaire. Replies revealed that a total of 151 of those who received Bachelor's degrees were thus employed, and 77 had returned to school to study for Master's degrees. Of the 70 who had received Master's degrees, 62 were employed and 8 were back working for Doctor's degrees. Of the 19 who received Doctor's degrees, 17 were employed in teaching and other wildlife work. Discrepancies between numbers quoted in this paragraph and those contained in Table 1 must be accounted for by degree holders who obtained work in non-wildlife lines or who are still looking for jobs.

The Employment Committee asked: "Has the employment situation, from your experience, improved or deteriorated for wildlife graduates during the past year?" In reply to this question, 4 stated it had improved, 11 that it had deteriorated, and 15 that it was about the same. The remaining 2 did not comment.

TABLE 2.—ENROLLMENTS BY CLASSES, AT SCHOOLS TEACHING WILDLIFE MANAGEMENT IN THE UNITED STATES, FOR THE 1949 FALL TERM

College or University	Freshmen	Sophomores	Juniors	Seniors	Total Undergrads.	Graduates	
						Masters	Doctors
1. Alabama Polytechnic Institute	0	2	0	0	2	2	0
2. California University	20	24	20	14	78	10	6
3. Colorado A & M College	*	17	22	26	65	0	0
4. Connecticut University	*	*	1	9	10	0	0
5. Cornell University	9	22	13	15	59	14	17
6. Idaho University	0	0	0	0	0	7	0
7. Illinois University	0	0	6	9	15	6	0
8. Iowa State College	0	0	8	6	14	6	8
9. Kansas University	*	*	*	*	*	3	6
10. Louisiana State University	0	0	0	0	0	9	0
11. Maine University	*	6	3	13	22	4	0
12. Massachusetts University	5	12	7	20	44	5	0
13. Michigan University	5*	11*	22	19	57	19	8
14. Michigan State College	22	12	32	12	78	10	1
15. Minnesota University	17	22	20	28	87	20	0
16. Missouri University	15	14	20	17	66	19	2
17. Montana State University	16	15	9	22	62	0	0
18. New Hampshire University	4	3	4	0	11	0	0
19. New York State College of Forestry	0	0	0	0	0	4	3
20. North Carolina State College	5	6	7	8	26	2	1
21. Ohio State University	20	17	20	25	82	10	2
22. Oklahoma A & M College	*	*	9	6	15	6	12
23. Oregon State College	33	63	30	51	177	14	1
24. Pennsylvania State College	0	0	0	0	0	15	0
25. Purdue University	1	3	3	3	10	0	0
26. South Dakota State College	12	19	15	7	53	0	0
27. Texas A & M College	31	21	30	16	98	7	5
28. Utah State Agricultural College	22	30	24	33	109	22	1
29. Virginia Polytechnic Institute	36†	45†	29†	28	138	11	0
30. Washington State College	0	10	6	15	31	5	3
31. Wisconsin University	0	0	0	0	0	7	5
32. Wyoming University	12	8	13	21	54	3	0
Totals	285	382	373	423	1,463	240	81

* Figures for freshmen and/or sophomores are inaccurate or unobtainable. Probable wild life students taking general college work are not classified.

† Both forestry and wildlife students, no distinction in the first 3 years.

The questionnaire ended with the following: "If your school is graduating more men than normal work opportunities will absorb, or if you anticipate you will be faced with that problem in the next few years, what are your ideas on how the base of employment can be broadened and what are you doing or planning to do about it? This elicited a variety of answers which can best be catalogued in the following sequence of emphasis:

1. Encourage graduates to get into conservation officer (game warden) work.

2. Obtain educational credits for teaching certificates.

3. Train more men for wildlife publicity activities.

4. Include fishery training.

5. Reduce enrollments.

In reviewing inquiry returns, this feature is highly significant: schools that stress graduate instruction of a small number of students, and who select those students with special care, anticipate no difficulty in the foreseeable future in finding satisfactory employment for their graduates. Over the years such training centers have built up a reputation for turning out a limited supply of highly polished products. They would be the very last to be affected by a glut of job candidates.

After tallying the recently graduated group and the number still in school who in one or more years will be competing for employment, we feel that a big oversupply of college-trained men is in the making. For example, the Pittman-Robertson program has been the outstanding source for employment of technically trained wildlife workers in recent years. At last count more than 400 college-trained workers were on the payrolls of State game departments in the several lines of approvable actions. That employment figure, when compared with the totals shown in Tables 1 and 2, gives real cause for concern.

Another disturbing element is that during the year ended June 30, 1949, the excise tax collections on sporting arms and ammunition which finances the 75 per cent Federal share of project costs on Pittman-Robertson work showed a 9 per cent decline from that of the previous year. Treasury reports on these deposits for the first 4 months of the year beginning July 1, 1949 disclose that a further slump is in the making. If this trend holds, no improvements can be anticipated in this line of employment next year; in fact, some cutbacks appear inevitable.

Some schools are beginning to broaden their course work to include more training for administrative positions. Others are pinpointing exploratory attention on the conservation officer (game warden) branch as a source of State employment for their graduates. There has been a decided swing in recent years toward raising the standards, salaries, and qualifications of the law enforcement group. We feel that the time will come when these workers will generally be made responsible for all activities of the game department in territories assigned them. This will include extension and publicity work, physical restoration and management tasks, and law enforcement. Instead of game wardens these men will be wildlife managers. The infiltration of technically trained workers into this branch of employment—which has about 10 wardens to every biologist in the State organizations—will strengthen one of the weakest links in the operational chain.

Some success has been achieved in getting technically trained wildlife workers into conservation officer jobs. But the small beachheads already carved out in that territory by former students need the expanded pressure that can come only from greater attention by the collegiate training centers. Institutions that require broader employment bases for their numerous graduates must work diligently and purposefully to put the expansion across. That will call for some redesigning of instruction schedules, with more emphasis on administrative phases and less on purely research aspects.

And if there is inclination to take a dim view of conservation officer tasks as a means for livelihood, consider this:

the workers in this class are the front men, the display and sales force of the State departments. They are the ones stationed at the source of supply who are in contact with the producing and harvesting public every hour of the working day. Their dealings with the public can spell the difference between success and failure in selling the results of carefully designed and thoroughly tested research and management. Many examples could be cited where products of much excellent fact finding have not been absorbed by the buying public in the past, because these field salesmen lacked understanding or confidence in the worth of newly developed practices and technics in the wildlife business.

As an illustration of an earlier parallel trend of technically trained men extending their employment horizon, consider the case of the Federal forest ranger. In the early days such employees were practically-trained men hired locally. Their work consisted primarily of organizing wild land areas to provide fire protection and control grazing. There were no forestry schools in existence. With the setting aside of Forest Reserves the need for professionally trained men became apparent, and during the first decade of the twentieth century forestry schools were established. As soon as trained men became available the practical woodman type of ranger was gradually replaced by the professionally trained wildland manager. The conversion is now practically completed, and within a few more years the last practical ranger will have retired and been replaced by a man who is technically trained. Thus the work of forest rangers on the National Forests has been classified as technical, and graduates from forestry and other schools have been recruited to fill these positions.

Some institutions are looking to the teaching profession as an employment opportunity for wildlife graduates. Students are being encouraged to get enough educational credits to qualify for teaching certificates. Better instruction of conservation subjects in the high schools and junior colleges is urgently needed, and surely the teaching profession need neither be shunned nor labeled a dead-end street. That fundamentally important activity needs no endorsement from us, but beyond that, many key workers in wildlife research and operations came from the teaching ranks.

Spreading the gospel through the written word is a top-level responsibility if wildlife conservation is to be sold to the public. The last several years have witnessed a decided upswing in the attention being given to this feature, particularly in the States. More money is being budgeted for publicity work than ever before. The scarcity of capable technically trained wildlife workers has necessitated the employment of men experienced in journalism who lack biological backgrounds. Wildlife students who have a flair for writing should be encouraged to minor in journalism so they can step into this avenue of employment after graduation.

In the Federal sphere, the Fish and Wildlife Service is by far the most prolific employer of technically trained wildlife talent. This agency has done considerable hiring since the war to fill vacancies in previously approved jobs and to gather new workers to staff programs developed from increased appropriations. Reaching outside the

organization for trained and experienced workers—particularly in the State setups—has left gaps that have been filled by upgrading other employees and creating openings down the line for recent graduates. This employment upsurge by the Service has about run its course, which will be reflected in lessened needs elsewhere. The National Park Service, Forest Service, Soil Conservation Service, and the U. S. Army Engineers offer some employment for trained wildlife workers, but numbers hired are not large.

If the wildlife employment area could be roped off, with entry being limited to men who could produce degrees in wildlife management from the schools listed in this report—and possibly a few more schools that we may have missed—the work-opportunity picture would be brightened immensely. Outside of wildlife research, however, that is not the case, and research falls far short of being a peak expenditure element. Even on the Pittman-Robertson program, investments by the States for fact-finding declined to 21 per cent of the total cash outlays last year, as compared to 32 per cent in the preceding year.

Junior, teachers, and other colleges that are not prepared to offer the comprehensive and high-caliber instruction of the schools named in this report, are training wildlifers. While it is impossible for such educational centers to turn out high-quality products, their graduates compete with better-trained men and intensify competition for available jobs. And the big oversupply of trained foresters can be figured as able competitors. Then there are the non-college, practically trained candidates who pit their talents and abilities against the collegiate group in the job marts. All of these competitors are qualified and able to offer keen competition when it comes to filling vacancies in the physical restoration and management branches of the wildlife enterprise, where more than 90 per cent of available money is being expended.

The enrollment and other facts developed from this study by the Employment Committee are disturbing. This is especially true when that information is weighed against the known downward trend in the hiring of men for conventional wildlife work. We are convinced that two simultaneous actions should be taken by those schools that are graduating large numbers of potential workers: the employment base must be expanded, and determined efforts made to reduce the numbers of graduates to what the field of work can reasonably be expected to absorb.

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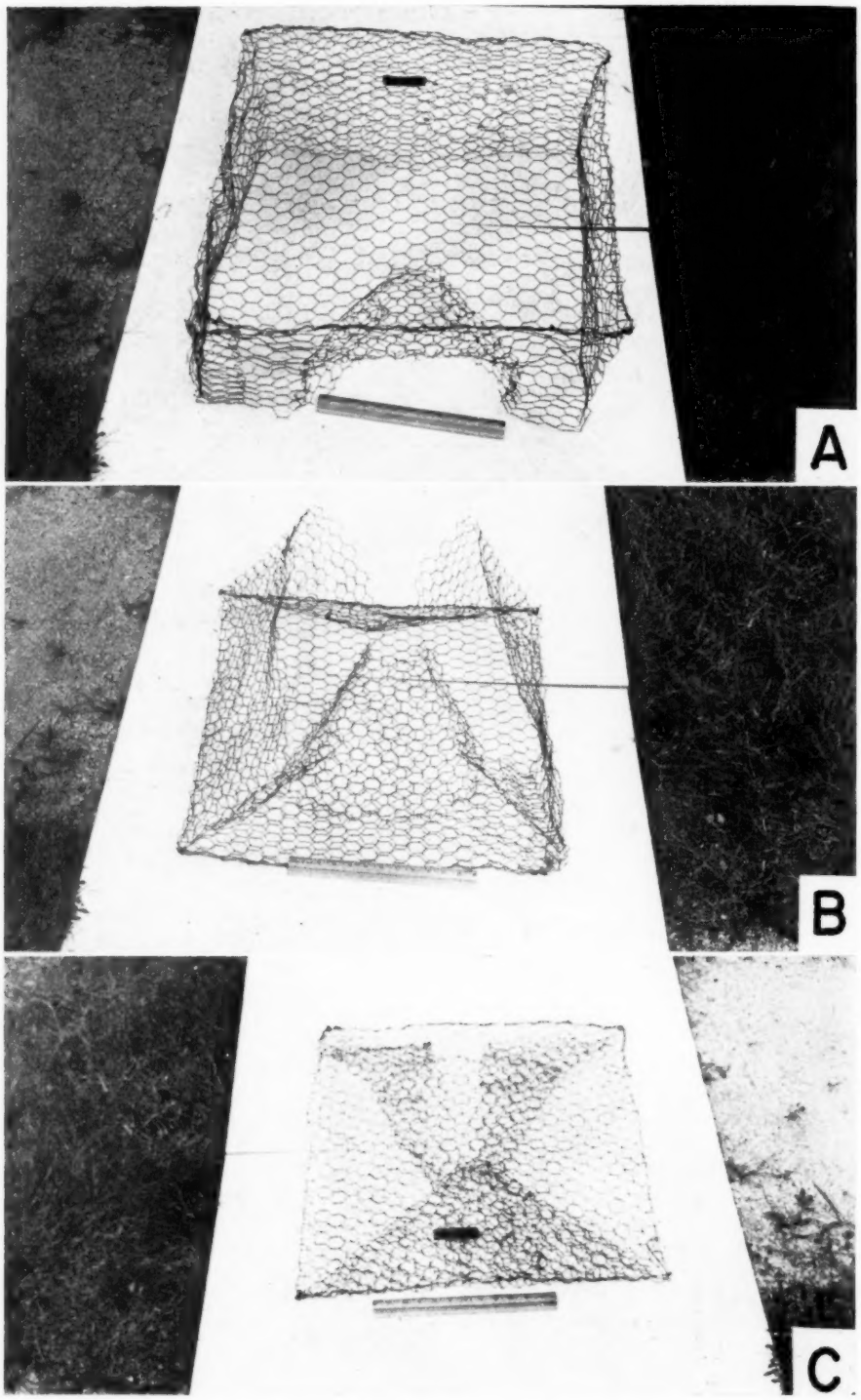

PLATE 8. Modified Stoddard quail trap. A. In working position. B. Partially collapsed. C. Fully collapsed.

BRIEFER ARTICLES

A MODIFIED STODDARD QUAIL TRAP

During investigations on the role of vitamin A as a survival factor of the bobwhite quail, *Colinus v. virginianus*, the need for a highly maneuverable quail trap was met by modifying the Stoddard type quail trap. The Stoddard trap, constructed of hardware cloth and a wooden frame, as used in many quail trapping studies, was too cumbersome and too expensive for trapping extensive areas for a short period of time. A trap was required that could be carried in quantities, that could be constructed cheaply and easily of materials available during the postwar shortage, and that would function efficiently. The trap designed (Plate 8) was constructed entirely of one-inch poultry netting bound together by lacing copper wire through the meshes. With the exception of the funnels, a strip of netting 12 feet by 2 feet was sufficient to construct two traps. To construct the traps, eight feet of the strip should be cut into two pieces 8 feet by one foot and the remaining 4 feet cut in half (2 feet by 2 feet). These four pieces form the sides and tops, respectively, of the two traps. The funnel-like entrance should be fastened to the side by the cut edges of the netting after the primary structure has been made.

The advantages of the modified Stoddard quail trap are as follows:

1. The traps were easily constructed at a low cost.
2. Collapsibility permitted convenient carrying of many traps (Plate 8 B, C show partially and completely collapsed traps, respectively).
3. The one-inch mesh permitted the escape of small birds which might have attracted predators or frightened quail from the trap. It also appeared to prevent excessive bruising of the quails' head and cere region.
4. Observations indicated that the birds showed no apparent fear of the trap and generally entered the trap upon first contact.
5. Factors 1, 2 and 4 permitted the use of many traps in an area and made it convenient to change trapping sites whenever necessary.
6. The small trap size permitted the easy removal of birds by extending one's hand through the funnel.
7. The small covey size in the areas studied prevented the maximum "holding capacity" from being discerned. The largest number caught at any one time was twelve birds.
8. During periods when the ground was frozen hooked spikes were used to fasten the trap to the ground. At other times any convenient weight placed on the trap proved satisfactory.
9. The ease with which the trap could be collapsed was helpful in allowing birds to escape when larger predators entered and collapsed the trap.
10. The small size of the trap permitted placing it in cover inaccessible to larger traps.—VINCENT SCHULTZ, *The Ohio Cooperative Wildlife Research Unit, Ohio State University, Columbus, Ohio.*

QUAIL PICKING UP LEAD SHOT

On March 10, 1948, the writer found a dead scaled quail (*Callipepla squamata pallida* Brewster) on a state game refuge near Albuquerque, N. Mex. This bird, which had probably been dead two or three days before being found, was autopsied as a matter of routine. No evidence of mechanical injury, disease or starvation could be found, but upon opening the gizzard, the writer was very much surprised to find 13 lead shot of various sizes ranging from about No. 8's to No. 4's. There was also the usual assortment of small seeds, sand and débris. The particular area where the bird ranged, though now a game refuge, is said to have been heavily shot over in former years by dove and quail hunters. Probably the soil contains much spent shot. This soil consists of fine, deep sand, rather

deficient in grit. Perhaps this fact influenced the quail to pick up the shot in its feeding, though this of course is pure conjecture.

The writer has searched the literature available to him, and can find no previous record of spent shot being found in quail stomachs. It is not claimed that the bird reported on here actually died of lead poisoning induced by the presence of the shot, but this appears to be at least a possibility.—HOWARD CAMPBELL, *Dept. of Game and Fish, Albuquerque, N. Mex.*

THE BULLFROG AS A PREDATOR ON DUCKLINGS

The ability of the bullfrog (*Rana catesbeiana*) to eat mice, snakes, crayfish, ducklings and other large food items is well documented in the literature. It has been observed by S. W. Frost (1935. The Food of *Rana catesbeiana* Shaw. Copeia, 1935, 1: 15–18) that after a large meal such as a mouse, a bullfrog can wait a long time for the next meal. During one season, a 200-gram bullfrog kept in captivity by Frost (op. cit.) consumed a total of about 2.1 times its body weight. It is of interest to note, however, that on occasion the capacity of the bullfrog as a gourmand may be quite amazing.

In June, 1944, a large bullfrog was brought to me for examination. It had been captured in the marshy estuary of the Blanche River at its junction with the Ottawa River below the city of Ottawa. In its stomach were the partially digested remains of one full-grown field mouse and two downy young black ducks which appeared to have been two or three days old when eaten.

No doubt young ducklings form a very readily available source of food for bullfrogs. In marshes where bullfrogs are common, they may play an important part in reducing broods of very young ducklings.—OLIVER H. HEWITT, *Dept. of Conservation, Cornell University, Ithaca, N. Y.*

THE BUYING OF DEN TREES FOR RACCOON MANAGEMENT

Many sportsmen's clubs have often thought the best way to increase raccoon populations was to save the raccoon dens from being needlessly destroyed during the cutting of timber. This idea was brought about by seeing the normal habitat of raccoons being stripped of all suitable den trees during timber cutting operations, and by seeing that the practice of the stocking of pen raised or wild trapped raccoons appeared to have no noticeable effect upon the raccoon population as a whole. In a few cases, hunters had asked timber cutters to "Save that old gum," and they found that 'coon still "treed" in these isolated dens.

At various times pressure of one kind or another has been brought on the game departments of the states to get assistance in the saving of den trees. It fell to the lot of the Ohio-Federal Aid Project 14-R, as a part of "Testing Methods of Increasing Raccoon Populations" to determine the value on a limited scale of this type of raccoon management.

PLAN OF ACTION

The plan of action was to locate a stand of mature timber of the most common species that was about to be cut, to locate the natural raccoon dens in the stand, to buy the trees with suitable raccoon brood dens from the owner of the land or the timber buyer as the case might be, and continually to check these dens to ascertain the value of such a management practice. Records of costs for determining dens, costs of buying, and occupancy records were to be kept.

PLAN OF OPERATIONS

The Ida B. Neldon farm of Coshocton County, Ohio was the first area used in this work. In the fifty acre woods, sixteen dens were located from the ground, and bought from the owner for a cost of $27.50 in the name of the Ohio Division of Conservation and Natural Resources. After climbing equipment was obtained and the trees were checked by climbing, it was found

UTILIZATION OF ELEVEN NATURAL DENS ON THE MCCABE FARM IN COSHOCTON COUNTY, OHIO

	Dates of Inspection						
	4/42	6/42	9/42	6/43	6/44	6/45	6/46
Occupied by raccoons	5	—	—	—	1	1	2
Used by raccoons	6	—	—	2	1	3	2
Used by squirrels (Gray or fox)	—	—	3	2	—	2	1
No. dens not used	—	11	8	6	6	2	3
No. dens destroyed by natural causes	—	—	—	1	3	3	3

that many of the trees did not contain good brood dens and so consequently, this area was discontinued and the majority of the records of this area have been omitted in this report.

The land owned by the McCabe heirs of Coshocton County, Ohio was next used in this work. The area was checked for den trees by actually climbing all potential trees, and in the 35-acre woodlot, 11 dens were located as suitable for brood dens for raccoons. These were bought in April 1942 by the Ohio Division of Conservation and Natural Resources from the timber buyer for a total of $35.50. In the 11 dens were five adult and nine cub raccoons.

AREA

The McCabe area is located in a mature stand of timber on a steep hillside overlooking a fertile stretch of bottomland along the Muskingum River. Much of the cropland is used for corn, and the hills are either in pasture or woodlots. The woods are almost continuous, and perhaps thirty per cent of the land is in timber of one sort or another.

The timber of the McCabe area was enormous with many trees of four feet d.b.h. leaves were out during the spring of 1942 and the dens were evaluated in terms of saw logs, and white numbers painted on them. The men who checked these trees could determine the extent of the cavity, and the value of the tree when cut as timber. Examinations were made by men with tree climbing irons, flashlights were used to check the dens, and the men came down from the trees using a swing in a half inch manila rope.

Of the 11 dens located as suitable to buy for use by raccoons, 10 were located in beech trees, and one in a maple tree. One additional and many rising 60 feet without a limb. The lower slopes were composed of beech (*Fagus grandifolia*), maple (*Acer saccharum*), and with some tulip poplar (*Liriodendron tulipifera*), but higher up the slopes the timber changed to white oak (*Quercus alba*), red oak (*Quercus rubrum*), and hickory (*Carya spp.*), and on the top of the ridge was a pure stand of chestnut oak (*Quercus montana*).

DENS

All potential dens were climbed before the den was found in a white oak tree, but was determined as more suitable to cut for timber. The 11 dens averaged 29.4 feet from the ground and 10 of the 11 were what might be called top snags.

Timber cutting began the following week and continued for three months.

DEN INSPECTION

The 11 den trees were checked twice more in 1942 and once each year in June during 1943, 1944, 1945 and 1946. The following is a record of the utilization of these dens during this time. It should be noted that three dens were destroyed by wind or by other natural causes when the surrounding woods were cut.

COSTS

The costs of locating the natural dens on the McCabe farm can be determined using present values as it took three men, three days' time, or a total of 9 man-days to check the woods and to locate the dens. Three men were necessary in order that one man could be on the ground in case of emergency, while

the other two were in the trees.

Tree climbing equipment, consisting of climbing irons, safety belts, safety straps, and rope, costs approximately $20.00 per man and with proper care, should last for years.

The actual cost of acquiring den trees has been given above and should compare approximately to the value of the tree for timber. There is a slight nuisance value to keep tops from falling into den trees, so perhaps payment should be slightly in excess of the actual timber value.

CONCLUSIONS

1. It is believed that den trees in timber to be cut can be bought economically for raccoons.

2. The raccoons used these den trees extensively before timbering started, immediately left the woods when timber cutting was in operation, and gradually returned to use the dens after timbering stopped.

3. In the case of the Ida B. Neldon Farm brood dens could not be determined from the ground.

4. Den trees when left to stand by themselves with the surrounding woods removed are susceptible to wind damage.

5. In this woods, beech trees were the most important tree for brood dens for raccoons.

6. Some den trees appear to be of greater value to the public as den trees than they are to the timber interests as board feet of lumber.

7. In these two cases, the method of buying den trees from the timber buyers appeared more satisfactory than buying them from the owner of the land.

8. It is believed that 'coon hunting organizations might well spend part of their money toward saving den trees by buying them in timber to be cut.—ROBERT T. BUTTERFIELD, *Conservation Commission of West Virginia, Buckhannon, W. Va.*

ESCAPE BEHAVIOR OF THE WHITE-TAILED DEER

The swimming powers of the white-tailed deer (*Odocoileus virginianus*) and the readiness with which it enters the water to escape pursuit are well known. The skulking habit of this species on land is equally well documented. The white-tail buck is especially likely to remain in its bed and allow a hunter to pass within a few feet without flushing, but it rarely exhibits this behavior when its trail is being followed by deer hounds. In many areas of the southeastern United States, the species is relentlessly pursued by hounds throughout the open season. In the coastal marshes and large, deep water swamp areas a deer finds little difficulty in throwing dogs off its trail by swimming; however, in the pocosins where scenting conditions are apparently ideal it would appear that these animals have little chance of escaping the tenacious pursuit of well trained deer hounds. Such, however, is not the case, for almost any hunter familiar with the shrub bog areas can cite examples of deer being only two or three minutes ahead of the dogs when they disappear completely. These escapes are attributed to almost every conceivable phenomenon from withholding scent to inexperienced pups leading the old dogs astray.

During a controlled hunt on the Holly Shelter Refuge, Pender County, North Carolina on November 15, 1947, an opportunity was provided to observe the actions of a young deer in escaping pursuit. The Refuge is composed of thousands of acres of pocosin bog, the dominant vegetation being a thick almost impenetrable tangle of *Zenobia nuda* and *Cyrilla racemiflora* interwined with *Smilax laurifolia* growing on a deep peat substratum. Water levels in the area vary from a few inches below the surface to two feet above. The deer spend a large portion of their time in the bay and when flushed in it seem reticent to leave. The drier sand ridges ("islands") are only slightly higher than the bog. Deer jumped by dogs on the higher ground frequently run a few minutes on the ridge and then penetrate the wettest and thickest part of the bay. Visibility is limited to a few feet necessitating trailing by sound and smell. A road built several miles into the bay makes it accessible to hunters. The removal of roadbed material from one side of the right-of-way resulted in a ditch varying from four to twelve feet wide and from a few

inches to six feet deep. Water flowing through the ditch has undercut the banks as much as three feet; however, the thick mat of roots keeps the edge intact. At the time of this observation the water was about a foot below the root mat. The ditch, at this point, was about ten feet wide and four feet deep.

Three hounds started a deer outside of the refuge and had been trailing it about thirty minutes before it entered the refuge and thick bay some two miles from our stand. The deer doubled back a number of times in the wet bay but was unable to escape. After almost an hour and a half of trailing, the dogs began to overtake the deer. Coming down-wind, it plunged into the water, swam the ditch, and climbed out on the opposite bank. The unspotted fawn was obviously nearing exhaustion, but on sighting one of us only six feet away, it recrossed the ditch and back-tracked rapidly for approximately two hundred yards. It veered sharply toward the ditch and was lost to sight. The hounds were less than five minutes behind it when they reached the initial crossing site. One of them quickly discovered the back-track and all tore off at full cry. On reaching the point where the trail again entered the ditch, they lost it instantly. After trying for several minutes to pick up the scent on both sides of the ditch, the dogs gave up and were easily captured. Some thirty minutes later, Mr. Keller, who had remained at the stand, noticed waves coming from beneath the overhanging bank. On investigating, he discovered the fawn, completely submerged with the exception of its nostrils, forehead and eyes. Even the tips of the ears were laid back along the neck and submerged. Apparently the deer made no effort to escape even though the dogs were within a few feet of it. It also remained perfectly still while it was under observation. After some sticks were thrown in its direction, the fawn came out on the bank, shook itself and trotted off. The deer had apparently entered the water and swum down the ditch under the overhanging bank. It was prevented from swimming farther by the junction of two ditches which would have necessitated its crossing open water. It preferred to skulk in the icy water under the bank rather than to continue attempting to escape by flight.

The foregoing observations may partially explain how even the best deer dogs lose a hot trail. These observations also indicate that the white-tail deer will exhibit its skulking behavior in the water.—FREDERICK S. BARKALOW, JR. and WALTER E. KELLER, *N. C. State College of Agriculture and Engineering, Raleigh, N. C.*

REVIEW

Bobwhites on the Rise, by Verne E. Davison. Charles Scribner's Sons, New York. 150 pp., illus. 1949. $3.75.

"Wildlife conservation in the last twenty-five years has failed to increase the bobwhite."

The cause of this obvious failure is not a lack of understanding of the bobwhite's requirements for maximum production and survival. It has resulted from our failure to coordinate good conservation methods with practical land management.

Verne Davison has studied and worked with the bobwhite quail for more than thirty years. As Regional Biologist for the United States Soil Conservation Service, he has had much experience in land management in the heart of the bobwhite's range. Now, in a clear and concise style, he has brought together the results of his research to show how the bobwhite can be increased through the application of techniques which are in keeping with the best land use.

Many fallacies in deep-rooted traditions regarding bobwhite are exposed. Mr. Davison demonstrates convincingly that good bobwhite management is much more simple than generally believed. The treatment of all types of farm land is discussed—from cropland to woodlot. Emphasis is placed on the practicability of handling bobwhite as an agricultural crop.

Mr. Davison discusses the problem of free-hunting, pointing out that the sporting public has an associated responsibility which goes far beyond the purchase of hunting licenses. The management required to produce adequate populations of bobwhite for sport can

be affected only by the landowner, with inducement and assistance by the sporting public. The machinery for the necessary organization and cooperation is already available in the Soil Conservation District.

"Bobwhites on the Rise" is one of the best "know how" books in the field of wildlife management. It is full of uncommon good sense. In the hands of cooperating landowners, sportsmen and wildlife managers, Mr. Davison's book is sure to benefit bobwhite and to place the conservation of all upland game on a more practical footing.—OLIVER H. HEWITT.

NOTES AND NEWS

NORTHEAST WILDLIFE CONFERENCE

This conference was held February 2, 3, and 4, 1950, at Syracuse, New York, with the New York State College of Forestry and the New York State Conservation Department acting as hosts. The meeting was sponsored jointly by the Northeast Section of the Wildlife Society, of which Ben Bradley was chairman, and the Northeast Association of Game and Fish Administrators, of which Ralph Carpenter was chairman.

The theme of the conference was "The Man With The Land," and attention was directed toward solution of landowner problems in fish and wildlife management, and 27 papers to that end were presented, together with five evening discussion sessions. The formal papers were assembled in mimeographed form into a volume of "Proceedings" which is being distributed by Phillip Barske, Secretary-Treasurer of the Northeast Section, Wildlife Society, at the price of $1.00.

Professor Ralph T. King, Chairman of the Program Committee, prepared the summary of attendance.

SUMMARY OF ATTENDANCE

1950 Northeast Wildlife Conference, Syracuse, New York, Feb. 2, 3 and 4

State, District or Province	State, Provincial or Federal Conservation Depts.	Conservation Organizations	Industrial Organizations	University and College Faculty	University and College Students	Totals
Connecticut	9			1	3	13
Delaware	8					8
District of Columbia	31[2]	1				32
Maine	14			2	8	24
Maryland	8	1		1		10
Massachusetts	9			2	15	26
Michigan[1]					1	1
New Hamsphire	18			1		19
New Jersey	4	1			1	6
New York	88	14	19[3]	31	64	216
Ohio[1]			3			3
Pennsylvania	2			3	4	9
Rhode Island	2					2
Vermont	9					9
West Virginia	18					18
Ontario	3			2	1	6
Quebec					1	1
Totals	223	17	22	43	98	403

[1] Not included in the Northeast Section.
[2] U. S. Fish and Wildlife Service, 25; U. S. Soil Conservation Service, 6.
[3] Including 8 farmers and land managers.

Members of the Wildlife Society	155
Members of the Northeast Section of the Wildlife Society	99
Members of the Northeast Association of Game and Fish Administrators	10
Members of the American Fisheries Society	62
Members of the International Association of Game, Fish and Conservation Commissioners	12